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ASTM BULLETIN

Published by
AMERICAN SOCIETY for TESTING MATERIALS

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The Society is not responsible, as a body, for the statements and opinions advanced in this publication.

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JANUARY—1944
No. 126

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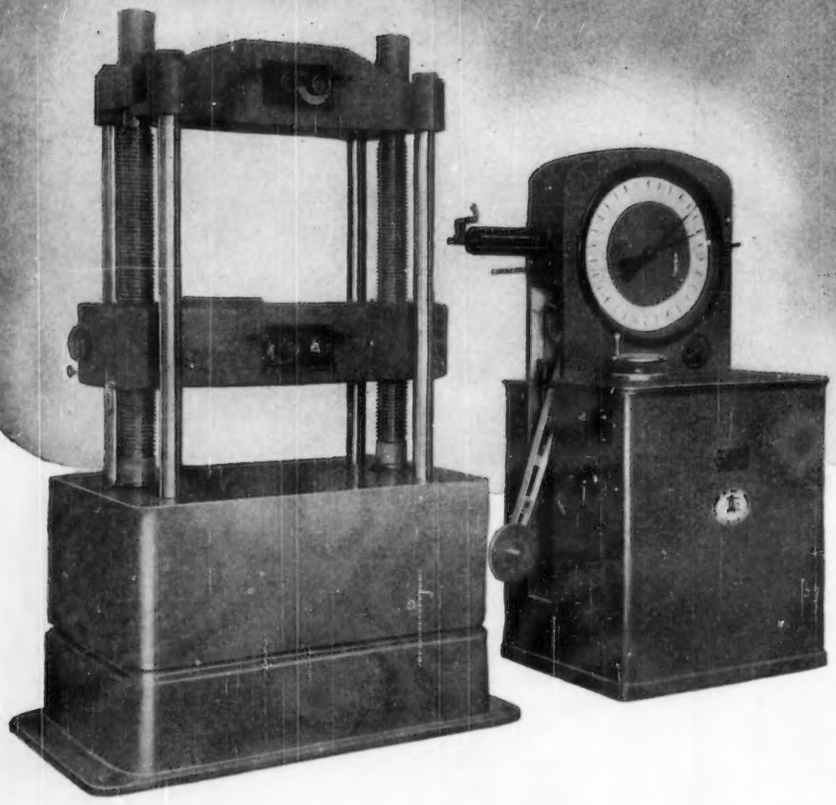

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"Promotion of Knowledge of Materials of Engineering and Standardization of Specifications and Methods of Testing"

TELEPHONE—PENnypacker 3545 R. E. Hess, Editor CABLE ADDRESS—TESTING

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Number 126 January 1944

Symposium on Synthetic Rubbers to Feature Spring Meeting, Cincinnati, March 2

Committee Week, February 28 to March 4

An outstanding technical Symposium on the Applications of Synthetic Rubbers will be the feature of the 1944 Spring Meeting to be held at the Netherland Plaza, Cincinnati, Ohio, on the morning and afternoon of Thursday, March 2 and this same subject but involving more of the industrial and economic phases will be discussed in an address on Thursday evening by J. L. Collyer, President, The B. F. Goodrich Co. The evening meeting at Taft Auditorium is being arranged by the Technical and Scientific Societies Council of Cincinnati, with A.S.T.M. participating.

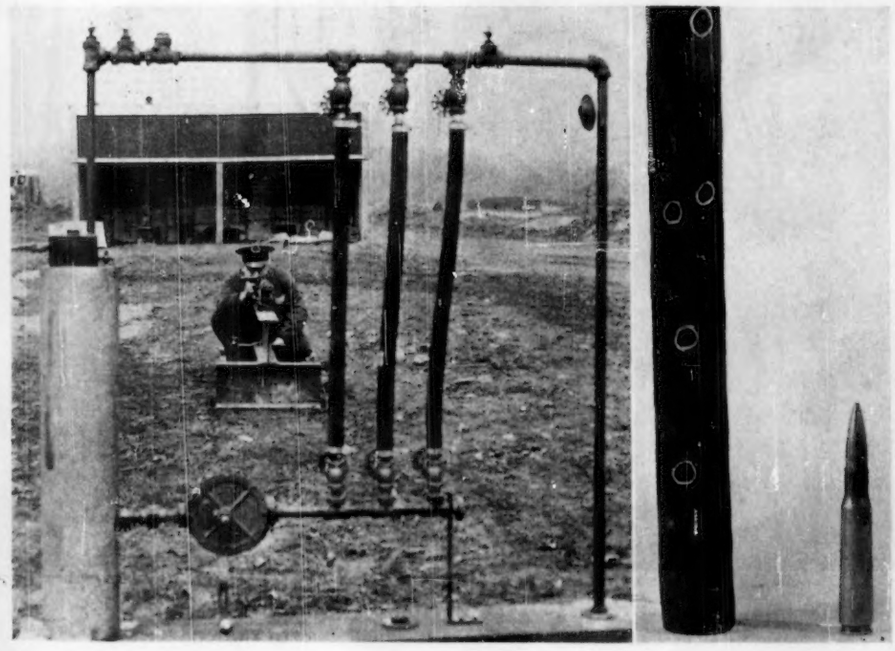
Throughout the week beginning Monday, February 28, there will be a number of meetings of A.S.T.M. technical committees, see preliminary list appearing later. This information will be supplemented by direct mail material sent to all members of the Society in February including cards for hotel reservations, committee meetings schedule, and the like.

As indicated in the December, 1943, Bulletin, Cincinnati was selected as the location for the Spring Meeting because of its industrial importance, the fact that no A.S.T.M. meeting has ever been held there, and the interest expressed by a number of A.S.T.M. members in the area.

While no formal local committee on arrangements has been organized, a number of members in the Cincinnati area attended a preliminary conference some time ago to consider plans, and various individuals have followed through, including in particular J. W. Bolton, The Lunkenheimer Co., and J. C. Pitzer, The Formica Insulation Co.

Technical Sessions on Synthetic Rubbers

In establishing the A.S.T.M. Spring Meetings which usually have included a technical symposium or group of technical papers featuring a one-day period during Committee Week, the Executive Committee had in mind stimulating interest in the Society's work in the particular area where the meeting was held, the desirability of affording another opportunity for presentation of technical papers other than at the annual meetings, and particularly providing by subsequent publication for the dissemination of important data on some timely subject in the field of engineering materials. Since the first Spring Meeting in 1930



B. F. Goodrich

Tests Bomber Equipment—behind sights of a 50-calibre machine gun, marksman riddles sections of new bullet-sealing synthetic rubber hose developed to replace heavy metal fuel feed systems on combat planes and thereby provide added fuel capacity.

Symposium on Applications of Synthetic Rubbers

Netherland Plaza, Cincinnati

Thursday, March 2

Morning Session—9.30 a.m.*

1. The Origin and Development of Synthetic Rubbers—Harry L. Fisher, U. S. Industrial Chemicals, Inc.
2. Physical Tests of Synthetic Rubber Products—Leslie V. Cooper, The Firestone Tire and Rubber Co.
3. Physical Properties of Synthetic Rubbers—John M. Ball, R. T. Vanderbilt Co.
4. Specifications for Synthetic Rubber Compounds—M. J. DeFrance, Goodyear Tire and Rubber Co.
5. Processing Characteristics of Synthetic Rubbers and Their Use in Extruded Products—A. E. Juve, The B. F. Goodrich Co.

Afternoon Session—1:30 p.m.*

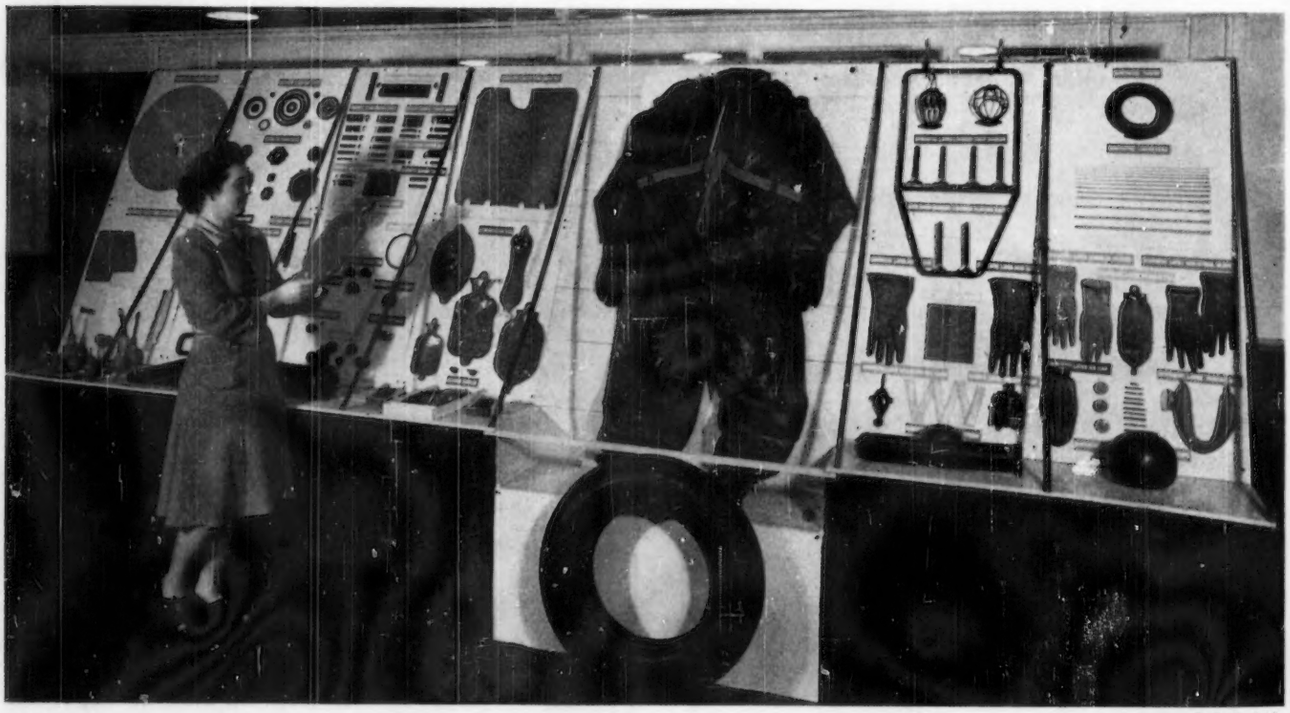
6. Synthetic Rubber Tires and Inner Tubes—P. M. Torrance, The Firestone Tire and Rubber Co.
7. Hose and Belting Made from Synthetic Rubber—W. L. White, Manhattan Rubber Mfg. Div., Raybestos-Manhattan, Inc.
8. The Use of Synthetic Rubbers in Molded Products—Merle Sanger, The General Tire and Rubber Co.
9. Synthetic Cellular Rubbers—Louis P. Gould, Inland Div., General Motors Corp.
10. Hard Rubber Products from Synthetics—Walter H. Juve, Consulting Rubber Technologist.
11. Use of Synthetic Rubbers for Insulated Wire and Cable—R. A. Schatzel, General Cable Corp.
12. The Use of Synthetic Rubber in Footwear—Stanton Glover, United States Rubber Co.
13. Synthetic Rubber Adhesives—Fred J. Wehmer, Minnesota Mining and Mfg. Co.

*Central Wartime

about a dozen publications of unquestioned technical worth have been issued and widely distributed. Some of the topics covered include the following: motor lubricants, lime, new materials in transportation, particle size measurement, color, plastics, paint, powder metallurgy, etc.

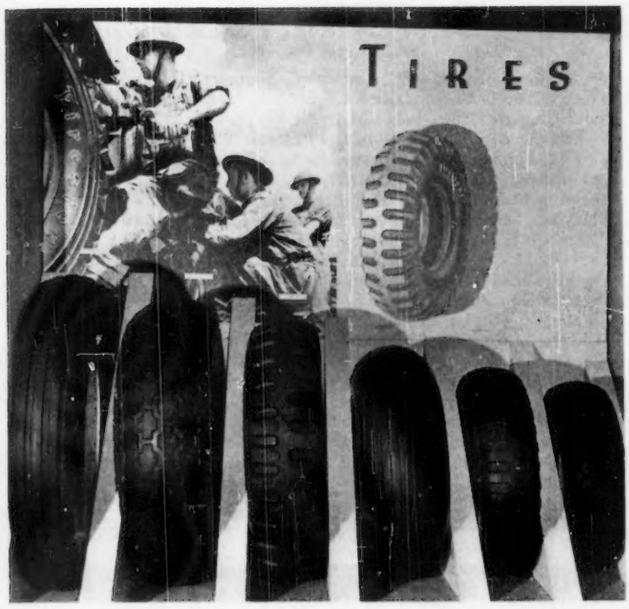
The subject chosen for the Cincinnati meeting, Applications of Synthetic Rubbers, is certainly timely because of the very insistent demand for authoritative technical data on products that are being made using various synthetic rubbers. Much has been already published dealing with chemistry and the manufacture of the crude synthetics, and these features will not be stressed in the symposium except where necessary for background information. The committee in charge headed by Arthur W. Carpenter, The B. F. Goodrich Co., Secretary of A.S.T.M. Committee D-11 on Rubber Products, is cognizant that our knowledge on the use of synthetics is in the development stage and that the situation is changing so rapidly that some of the information which would be given might become obsolete fairly soon. However, the committee feels that by arranging for the participation in the symposium of outstanding authorities, the information which is presented and which it is hoped can subsequently be published will be reliable and should be of very distinct assistance to all those directly concerned even though some of the data may need to be revised later as experience with the use of the various products increases. Essentially the symposium will stress the applicability of the different materials in the various services in industry.

Plans are being worked out by the committee so that discussion during the two technical sessions will be in written form, or if from the floor, limited to questions



B. F. Goodrich

A display showing the wide range of products made from synthetic rubbers—tires, bottles, gloves, tubing, icebags, masks, rings, cups, bushings, weather seals, gaskets, etc.



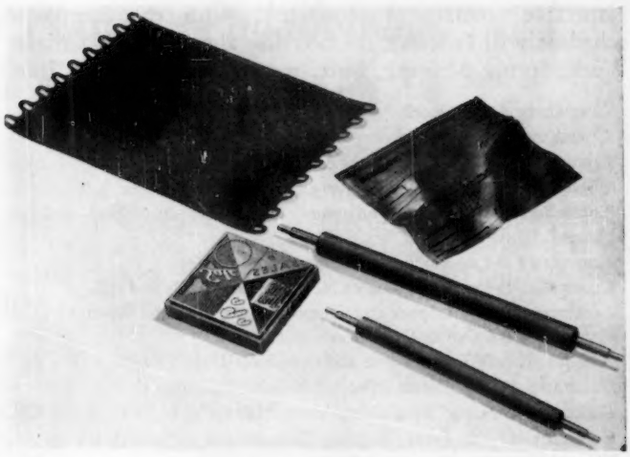
Firestone

Tires of many sizes and designs are playing a major role in the war effort, and this picture shows tires designed for a variety of uses. The tire at the left is a ribbed implement tire. Down the line, in succession, are an earth-mover tire, a combat tire, an airplane tire, a military tire, and a sand tire.

dealing only with information included in the papers presented.

At an all-day meeting at A.S.T.M. Headquarters early in December the Symposium Committee perfected its plans, selecting subjects to be covered and also suggested authors. Subsequently, the program has been practically completed, the latest version on page 6. Each of the speakers is an unquestioned authority in the field he is covering.

A cordial invitation is extended to everyone concerned with the subject to attend the two sessions.



Goodyear

Synthetic rubbers in the printing field.

Meetings During Committee Week

The number of committees participating in Committee Week usually held during the first week in March each year varies depending upon the status of the work before the individual groups. Also some committees wish to meet at a different time and locality, although occasionally one or more of these groups will participate in Committee Week. Those which have thus far signified their intention of participating in the Cincinnati meetings are listed below. It should be noted that advance schedules of committee meetings will be distributed to all members of the committees participating. There will be a composit schedule and also individual schedules sent by the

Synthetic rubber tires are subjected to many rigid tests in an effort to predetermine the amount of punishment a tire will take. One of the most severe tests is the high-speed operational test shown here. A "load" is placed on the tire by pressure through a revolving test wheel and the tire is speeded up to as much as 70 mi. per hr. Instruments record the heat build-up within the tire and and show how tire responds under driving conditions.

Testing bullet-sealing synthetic rubber fuel cells for combat planes.

B. F. Goodrich

Firestone

respective committee secretaries. With the composite schedule will be other information about the Committee Week, Spring Meeting, hotel reservations, and the like.

Committee A-1 on Steel
Committee A-3 on Cast Iron
Committee A-5 on Corrosion of Iron and Steel
Committee A-7 on Malleable Iron Castings
Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel, and Related Alloys
Committee B-1 on Copper and Copper Alloy Wires
Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys
Committee B-5 on Copper and Copper Alloys, Cast and Wrought
Committee B-6 on Die-Cast Metals and Alloys
Subcommittee V on Exposure and Corrosion Tests, of B-7
Committee B-8 on Electrodeposited Metallic Coatings
Committee C-16 on Thermal Insulating Materials
Committee D-1 on Paint, Varnish, Lacquer, and Related Products
Committee D-2 on Petroleum Products and Lubricants
Committee D-4 on Road and Paving Materials
Committee D-5 on Coal and Coke
Committee D-11 on Rubber Products
Committee D-17 on Naval Stores
Subcommittee I on Samples and IV on Photography, of E-4

Representative group of different shaped parts fabricated from synthetic rubbers.

Goodyear

The Search That Never Ends

In the industrial life of America, research has been of constantly increasing importance. And today it is a national resource, for the research of industrial and college laboratories is proving its value in War. . . .

The fields of inquiry have broadened and deepened through these years; they inquire into all the sciences and engineering arts which have any promise of improving the telephone. Much has been learned but still more will be because their search goes on. . . .

Improvements in industry can be left to chance in the hope that some one, sometime, will think of something useful; that some good invention will turn up.

The other way to make improvements is to organize so that new knowledge shall always be coming from researches in the fundamental sciences and engineering arts on which the business is based. From that steady stream will arise inventions and new methods, new materials and improved products. . . .

"Research is an effort of the mind to comprehend relationships no one has previously known; and it is practical as well as theoretcial." —Bell Telephone Laboratories

From a current advertisement of the Bell Telephone System.

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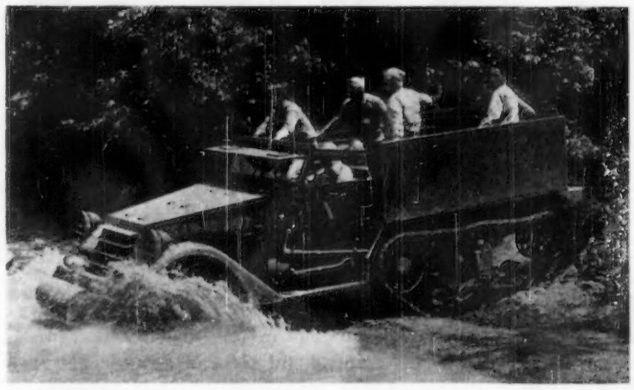
In attendance at the Philadelphia meeting when the symposium arrangement was drafted were M. J. DeFrance, The Goodyear Tire & Rubber Co., and E. N. Cunningham, Stanco Distributors, Inc.



Firestone

Plunging into a water ford at high speed, this half-track combat vehicle is operating under typical punishment. The rubber and metal half-tracks enable military vehicles to keep advancing in terrain where vehicles equipped entirely with tires would find traction impossible. The half-tracks also are far less vulnerable to enemy fire than are tires.

A.S.T.M. Participates in Production Conference

UNDER THE auspices of the Engineering Societies Committee on War Production on which the Society is represented by Myron Park Davis, Otis Elevator Co., chairman of the A.S.T.M. New York District Committee, there was held on January 14 at the Hotel Commodore a War Production Conference featuring several panel meetings and a dinner. Two active A.S.T.M. members were chief speakers at the panel dealing with chemical industry involving types of plastics and engineering properties and uses. Dr. R. J. Moore, Bakelite Corp., spoke on "Synthetic Resin Plastics—Introduction," and Robert Burns, Bell Telephone Laboratories, Inc., chairman of A.S.T.M. Committee D-20 on Plastics, discussed "Testing and Comparison of Molding Materials." Quite a number of other members participated in other panels or served as presiding officers in the sessions. Two each on metallurgical problems and on foundry industries included a number of active A.S.T.M. committee people.

Extensive Symposium on Plastics, Philadelphia, February 22 and 23

A Symposium on Plastics that should be of widespread interest to all concerned with this still rapidly growing field will be held in Philadelphia under the joint auspices of the A.S.T.M. Philadelphia District Committee and Committees D-9 on Electrical Insulating Materials and D-20 on Plastics, during the four-day meetings of the latter two groups, February 21 to 24. Committee meetings will be held at the Benjamin Franklin Hotel, D-9 on the first two days, and D-20 on the twenty-third and twenty-fourth. The first technical session in the symposium will be at the Franklin Institute on the Parkway Tuesday night, February 22, and the final and equally interesting session on February 23 in the Ballroom of the Benjamin Franklin Hotel.

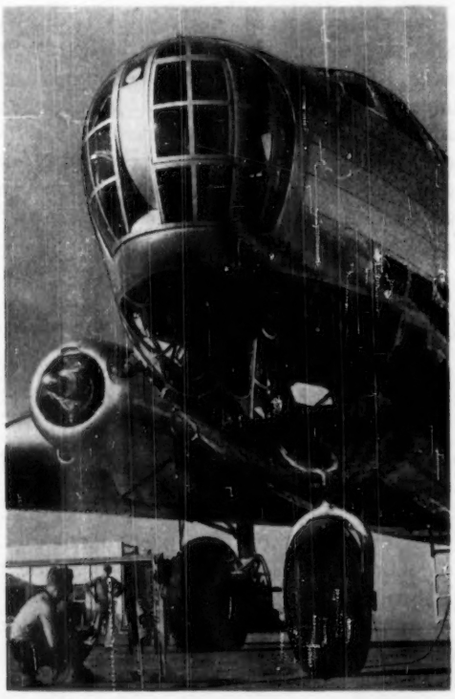
Development

The Society has not had a formal symposium on plastics since the one in Rochester during the 1938 Spring Meeting, which was sponsored by the then newly organized Committee D-20 on Plastics. There was considerable interest in the subsequent publication, which has been widely distributed and has been out of print for several months. Since then there have been a number of technical papers on various aspects of plastics testing and properties presented at annual meetings of the Society; and two of the best attended meetings sponsored by District Committees, one in Chicago and another in Philadelphia, featured groups of speakers in this field.

Since 1938 and particularly in the past year or two, there have been many notable developments, not the least of which has been the important work on specifications carried out through Committee D-20. All of these factors led the Philadelphia District Committee to propose the organization of another symposium. The program follows.

Although a somewhat rigorous time schedule will be in effect, it is believed ample time is being given each author to cover the high points of his contribution. Following each paper it is planned to have a short period for presentation of both written and oral discussion and questions.

The eighth item dealing with families of plastics and really a climax of the whole endeavor merits some ex-



The importance of plastics, in this case of the acrylate family, is shown in this bomber nose and turret.

Symposium on Plastics

First Session—Tuesday, February 22, 8 p.m. sharp—Franklin Institute

Technical Chairman: Robert Burns, Bell Telephone Laboratories, Inc., Chairman A.S.T.M. Committee D-20 on Plastics

1. Introduction to Symposium—Robert Burns
2. Heat Resistance of Laminated Plastics[1]—E. O. Hausmann, and A. E. Parkinson, Continental-Diamond Fibre Co., Newark, Del.; and G. H. Mains, National Vulcanized Fibre Co., Wilmington, Del.
3. Effect of Environmental Conditions on the Mechanical Properties of Plastics—T. S. Carswell and H. K. Nason, Monsanto Chemical Co., Springfield, Mass.
4. Diffusion of Water Through Plastics—George Deeg, Jr., and Carl J. Frosch, Bell Telephone Labs., Inc., Murray Hill, N. J.
5. Testing of Nonrigid Plastics—R. F. Clash, Jr., and R. M. Berg, Bakelite Corp., Bound Brook, N. J.

Second Session—Wednesday, February 23, 8 p.m. sharp—Benjamin Franklin Hotel

Technical Chairman: Myron Park Davis, Otis Elevator Co., Chairman A.S.T.M. Committee D-9 on Electrical Insulating Materials, and New York District Committee

6. The Behavior of Plastics under Repeated Stress—B. J. Lazan, and A. Yongiadis, Sonntag Scientific Corp., Greenwich, Conn.
7. Testing in Connection with the Development of Strong Plastics for Aircraft—Henry Sang, Aeronautical Engineer, Naval Air Experimental Station, Philadelphia, Pa.
8. Summary of Properties, Uses and Salient Features of Families of Plastics—G. M. Kline, National Bureau of Standards, Washington, D. C.

Participating in this section of the symposium will be the following:

I. Phenolic Materials—Molded and Laminated—W. A. Evans, Bell Telephone Laboratories, Inc., New York, N. Y.

II. Urea and Melamine Plastics—Ladislav Boor, American Cyanamid Co., Stamford, Conn.

III. Allyls—Franklin Strain, Columbia Chemical Div., Pittsburgh Plate Glass Co., Barberton, Ohio

IV. Vinyl Plastics—Rigid and Nonrigid—H. L. Drukker, Carbide and Carbon Chemicals Corp., New York, N. Y.

V. Acrylates—Willard F. Bartoe, Röhm & Haas Co., Philadelphia, Pa.

VI. Polystyrenes—W. C. Goggin, Dow Chemical Co., Midland, Mich.

VII. Cellulose Plastics—W. E. Gloor, Hercules Powder Co., Parlin, N. J.

[1] This paper represents the work of Section III on Thermal Properties of Subcommittee III of Committee D-9 on Electrical Insulating Materials.

planation. It was obvious that any worth while symposium and ensuing publication would need to devote considerable emphasis to the properties and salient features of the various groups of plastics. Furthermore, to have this material, plus papers on testing and such problems, presented in two sessions was an almost impossible situation. Some solution was necessary. The committee in charge approached Dr. Kline, who has done so much important work for the Society as chairman of Committee D-20's Specifications Subcommittee, and he agreed to summarize and present the data furnished him by the authorities covering each plastics group, and to add such supplementary information on the minor groups as would present a well-rounded picture. Each of the authors in this section on plastics families will follow a somewhat similar outline, but will, of course, stress the particular features of their groups which are of concern to the designer and user of plastics. Following an introduction with some notes on outstanding characteristics and types, it is expected there will be suitable reference to fabricating methods, sufficient details on properties which will probably comprise the major part of the contributions, and then discussion dealing with uses of the groups, prewar applications, some applications aiding the war effort, and probably some looks into the future. Just how much can be said on war applications will depend on the nature of the product and the necessity of withholding any information that would aid the enemy.

A cordial invitation is extended to all members and committee members of the Society to attend these technical sessions and to bring their associates and others interested. Invitations are being extended to several local branches of national societies in the Philadelphia area.

Editor's Note.—All photographs on the ensuing pages showing applications of plastics, courtesy of *Modern Plastics* Magazine.

The Symposium Committee consisting of Messrs. F. G. Tatnall, The Baldwin Locomotive Works, Chairman of the Philadelphia District Committee, G. H. Mains, National Vulcanized Fibre Co., and R. W. Orr, RCA Victor Division of Radio Corporation of America, District Secretary has had very close cooperation from the authorities who were selected to present the papers and cover the topics assigned. In the section on plastics families many of the authors have solicited the aid of technical people in other organizations.

It is planned to issue the papers which will include the material as prepared by the seven contributors in the section on groups of plastics, but no definite time of publication can be given. This will be announced later.

The abstracts which follow will convey some idea of problems to be discussed.

Those concerned with the Symposium on Plastics will no doubt wish to review the short abstracts of papers which appear below. No preprints of the papers have been issued, although extra copies of the manuscripts have been furnished in a number of cases for use by other authorities for the purpose of presenting discussion.

Abstracts of Technical Papers in Symposium on Plastics

Introduction to Symposium

By Robert Burns

The Introduction traces the development of standardization work in specifications and methods of Test since the previous Plastics Symposium in 1937. Since Committee D-20 on Plastics was organized at approximately that same time, the review constitutes a brief history of the committee and of its accomplishments in the seven intervening years.

The intensive study of plastics was inaugurated in Committee D-9 on Electrical Insulating Materials in the early twenties and was carried on for some 15 years as an integral part of the Society's work on insulating materials. During that period many of the fundamental requirements for the evaluation of organic molding compounds were established, and the passing years witnessed the gradual competence of a relatively small group of bewildered technicians in this new and amazing field.

In 1937, with the increasingly extensive use of thermoplastics and the expanding utilization of thermosets, the A.S.T.M. Executive Committee created the new Committee D-20 thereby extending to plastics the autonomy and prestige commensurate with the rapid growth and national importance of a great industry.

Building on the firm foundation constructed by Committee D-9, holding firmly to the traditionally democratic concepts which are the essence of A.S.T.M.'s technical power, the new committee has gone forward with vigor and courage. The many specifications and methods of test which have been published, and the close cooperation of the Committee with the Military Services are an outstanding tribute to the men who eschew personal glory for the privilege of demonstrating that a group of free Americans can advance technically faster and better than anyone else on the face of the earth.

Effect of Environmental Conditions on the Mechanical Properties of Organic Plastics

By T. S. Carswell and H. K. Nason

Although an intimate knowledge of the behavior of materials under all conditions of use has long been recognized as a prerequisite to intelligent engineering design, relatively little information on the mechanical properties of organic plastics, and particularly on the effect of environmental conditions on these properties, has been available until recently. Under the impetus of war demands, however, much work has been done along these lines, and the past three years have seen a very great extension of our knowledge of plastics properties.

The cost of failure of a piece of fighting machinery is too great to permit any doubt concerning the dependable func-

tioning of every part and component. Behavior must be predictable, and, since this war is being fought at extremes of environmental conditions hitherto unencountered, reliable test data on material properties, as well as service data on components, have been determined over a wide range of these conditions.

Environmental factors which must be considered in work of this kind include temperature, moisture, contact with chemicals, light, oxidation, the composite effects known as weathering, and the time scales of action of the principal mechanical stresses.

Properties, whose degree of sensitivity to the above factors must be evaluated, include tensile, flexural, compressive and shear strengths, stiffness and rigidity, ductility, shock resistance, creep and stress endurance, fatigue resistance, dimensional stability and physical integrity.

Data of this type for thermoplastic, thermosetting, and laminated organic plastic materials are reviewed, and are compared with similar data for metals and woods. In general, increased temperature and increased moisture content tend to reduce strength and rigidity, increase ductility and shock resistance, accentuate creep and dimensional change. Lower temperatures and reduced moisture contents, conversely, tend to increase strength and rigidity, decrease ductility and creep rate, and accentuate brittleness. Rapid or prolonged long range temperature changes may cause cracking or permanent change of dimension and shape. Prolonged exposure to high temperature, high moisture contents, actinic radiation, weathering, or certain chemicals may promote chemical alteration with accompanying deterioration of mechanical properties. The degree to which these effects occur is dependent upon the nature of the particular plastic and varies from very slight to severe. In general, metals show analogous behavior, although over a broader temperature scale. Wood behaves very much like an anisotropic cellulose-base laminate.

Specific data are presented for a number of commonly used plastics, and some predictions concerning future developments are hazarded.

Diffusion of Water through Plastics

By J. Deeg, Jr., and C. J. Frosch

DATA ARE PRESENTED on the rate of water diffusion through various plastics at equilibrium conditions. The effects of composition on the diffusion rate are discussed and illustrated by data. Although a diffusion value is calculated for each material, based on Fick's law, the latter is shown to be invalid for water sorbing systems. In these the rate of diffusion is shown to increase with the water content. A correlation of diffusion data on water sorbing plastic systems, therefore, is only possible when the same vapor pressures are employed to establish the differential. A comparison of the effective moisture sealing characteristics of such plastics is not necessarily the same at any other set of moisture conditions. For engineering purposes this implies that the rate of moisture diffusion must be integrated over the entire moisture range to be encountered in any particular application in order to select the proper plastic composition for sealing purposes.

Stiffness and Brittleness Properties of Nonrigid Vinyl Chloride-Acetate Resin Compounds

By R. F. Clash, Jr., and R. M. Berg

THE PHYSICAL properties of elastomers are in general markedly dependent on temperature. A number of tests used to evaluate the change in mechanical properties of elastomeric materials have been reported in the literature. The authors of this paper selected: (*a*) The Stiffness in Flexure (A.S.T.M. D 747), (*b*) Stiffness in Torsion (Bakelite Torsion Test), and (*c*) Brittleness Temperature (A.S.T.M. D 746) as indices of the mechanical behavior of nonrigid vinyl chloride-acetate resin plastics at normal and subnormal temperatures.

A correlation between the stiffness in flexure and the stiffness in torsion is shown. Stiffness-temperature data are shown graphically for the cases of tricresyl phosphate, dioctyl phthalate, and trioctyl phosphate in "Vinylite" resin VYNW for a range of concentrations. Brittleness data are also shown for the same compounds.

The Behavior of Plastics Under Repeated Stress

By B. J. Lazan and A. Yorgiadis

THE THREE-FOLD function of this paper is:

(1) To discuss the nature of the basic dynamic properties of plastics that affect their behavior and serviceability as structural members subjected to dynamic forces.

(2) To review, classify, and evaluate the various testing machines and methods by which an attempt is made to determine these basic dynamic properties.

(3) To classify and summarize the dynamic properties of plastics as indicated by the dynamic testing machines.

The importance of the fatigue test as a criterion for serviceability is presented. The various types of fatigue testing machines are described and classified as fixed-alternating force or fixed-alternating deflection machines. The advantages and limitations of each type of machine are discussed. Such factors as temperature, humidity, overstressing, understressing, rest periods, stress concentration, size effect, etc., which affect the fatigue life of materials are considered. A discussion is presented of the correlation between fatigue strength and better known static mechanical properties.

The repeated impact test is briefly described.

Plastics possess a much higher damping capacity than other structural materials. Mention is made of the various methods commonly used to determine this property. The advantages and limitations of each method are analyzed. The variation in damping capacity with magnitude of stress, and the correlation between damping capacity and other properties are presented.

Previous experiments indicate that a difference exists between the static and dynamic moduli of elasticity of plastics. The significance of this difference as related to the interpretation of fatigue testing data and the calculation of natural frequency is analyzed.

Unexplored dynamic mechanical properties, such as the creep of plastics under steady force with small vibration superimposed, are mentioned and future work suggested.

Plastics are briefly compared with other structural materials as regard their behavior under repeated forces.

Testing in Connection with the Development of Strong Plastics for Aircraft

By Henry Sang

The Naval Air Experimental Station is engaged in the development and testing of strong plastics for aircraft. Part of this work involves the development of testing and inspection procedures for use with forthcoming specifications.

In evaluating strong materials for use in aircraft, weight limitations require that the properties be known to a high degree of accuracy. The compressive yield strength and modulus of elasticity are of critical importance. Other important necessary characteristics are resistance to deterioration under repeated stress, fatigue, exposure to extreme climatic conditions and rough handling. The thermosetting laminated plastics are the only existing type which will meet all these requirements.

Examination of a typical commercial laminate in comparison with a typical structural metal reveals that the plastic is particularly deficient in tensile strength and compressive yield strength. In general, the laminates suffer from lack of homogeneity and of adequate bonding between laminas; poor resistance to heat and dimensional instability. Their behavior under repeated stress is questionable. In fatigue they appear inferior to the structural metals. In a twenty-day accelerated weathering test intended to simulate an extended period of service, most laminates stand up very well, but certain types deteriorate rapidly.

Most of the properties of laminates can be made to compare favorably with structural metals, by the use of strong reinforcements and special processing techniques.

Test methods used by the N.A.E.S. follow Federal Specification L-P-406 for the most part. Principal differences are the method of defining yield strength in tension, compression and flexure; and the procedure in the fatigue test. Tests not described in L-P-406 include the sheet compression test, toughness test, warpage test, accelerated weathering test, repeated stress tests, and formability test. These procedures, most of which are still in development stages, are described, in addition to descriptions of specific techniques and apparatus used in the better known tests.

The manner in which testing is carried out at the N.A.E.S. is described by following the progress of a test through the laboratory, from the receipt of the sample sheet of material to the completion of the tests.

Introduction to Summary of Properties, Uses, and Salient Features of Families of Plastics

By Gordon M. Kline

The American Society for Testing Materials held a Symposium on Plastics in March, 1938, a few months after the organization of its Committee D-20 on Plastics. The emphasis at that time was on the development of standard methods of test. These were needed to obtain numerical data to replace the qualitative superlatives which were commonly employed in describing the properties of plastics.

Three years later a National Emergency brought a demand for engineering data on plastic materials which were needed to fill vital roles in war equipment. Fortunately, rapid progress had been made on obtaining the information required to reach agreement on methods of test. Test methods were adopted and used to accumulate a still meager background of knowledge of plastics in terms familiar to designers and structural engineers. These test data were used as the basis for the preparation of materials specifications.

Another phase of the technical growth of plastics is at hand. There is a demand for classification and standardization of plastic materials analogous to that which has been applied to the steel and non-ferrous alloys. Engineers want simple designations and basic specifications for a relatively limited number of grades of each type of plastic.

There is a tendency to overlook the fact that each chemical type of plastic has its inherent properties. Thus, such terms as phenol-formaldehyde, urea-formaldehyde, allyl, vinyl, acrylic, styrene, and cellulose applied to plastic compositions mean just as much to plastics engineers as such terms as steel, copper, zinc, aluminum, nickel, magnesium, and tungsten applied to metallic alloys mean to the engineers specializing in metals. This part of the 1944 Symposium on Plastics has been arranged to present a review of the properties, processing, and applications of each of the various families of plastics. This is the foundation on which the future of the plastics industry is based. It is a future full of promise and adventure because of the very multiplicity and versatility of materials which perplex the uninitiated.

Phenolic Materials

By W. A. Evans

It is believed that the history and early developments of the phenol formaldehyde resin need no further repetition. A short review of the essential properties, such as ease of molding, hardness, strength, resistance to heat and solvents, and insulation resistance, illustrates why it is so well adapted as a material of construction, especially for electrical purposes. A table of the ten more generally used types of molding compounds and the various types of laminated sheets, with their characteristic requirements and identification, is given. There is a brief outline of the compression, transfer, and jet types of fabrication with a side light on the value of electronic heating of preforms and its application to laminated paper, fabric and wood sheet.

Some of the essential properties of the ten types are discussed and it is pointed out how these types may be selected for different uses and how specific needs led to their development. A companion paper by Mr. J. J. Martin illustrates how the characteristics of shrinkage and cold flow are determined. (Note.—Mr. Martin describes the procedure used to separate cold flow and shrinkage components of three types of materials: (1) Laminated phenolic sheet having a resin content in the body and surface paper comparable to that of Grade XXX, Type 1 A.S.T.M. Specifications for Laminated Thermosetting Materials D 709. This is a cellulose paper base, designated electrical and high humidity. (2) Laminated phenolic sheet made entirely from surface paper comparable to that

used in the preparation of A.S.T.M. D 709, Type 1, Grade XXX material. (3) Laminated phenolic sheet prepared from body and surface paper which was impregnated with a special phenolic resin.)

Some of the commercial applications are listed and it is shown how these applications have called for the use of certain types of materials.

The war needs have changed the emphasis of the use of certain types of materials inclining more to the use of low loss and high impact materials.

In conclusion, some of the postwar applications and methods of fabrication are considered.

Melamine plastics are used among other things for dishes in the U. S. Navy.

Urea- and Melamine-Formaldehyde

By Ladislav Boor

I. UREA-FORMALDEHYDE resins were introduced commercially in the United States in 1928. Although urea had been synthesized as early as 1838 and is perhaps the first organic chemical developed, commercial use of it in the form of a resin and molding compound occurred almost a century later.

All urea resins are partially soluble and fusible. These resins, however, when subjected to temperatures of approximately 275 to 315 F. undergo a rapid chemical change which renders them insoluble, infusible, and generally chemically inert.

Although ureas are best known as a molding material, they are supplied in various forms for many and diversified applications. For example, urea resins in solution are used for the impregnation of coating of paper and fabrics and in the formulation of lacquers and baking enamels.

Layers of paper or cloth impregnated with urea resins, when subjected to heat and pressure, are formed into homogeneous laminated panels. Since the resin is colorless, brilliant opaque or translucent colors may be produced, ranging from black to a translucent pearl. Resins in solution may be used to serve as a stiffening agent for fabrics, or to render them creaseproof.

Urea resins are likewise used in compounding hot set and cold set adhesives for paper board, corrugated fiber, and plywood.

In combination with a highly divided alpha-cellulose pulp, ureas are supplied in the form of a molding compound. These molding materials may be obtained in practically any color, either translucent or opaque. When subjected to the combined action of heat and pressure in steel molds, the compound assumes the shape of the die, becomes hard and rigid, and usually highly polished.

Probably the outstanding properties of urea-formaldehyde moldings are brilliance and permanence of color, lack of odor and taste, speed of molding, light weight, and electrical insulating characteristics. Another characteristic is the ability of molded urea-formaldehyde materials to diffuse transmitted light.

Applications to which this compound was put prior to the war were:

1. BUTTONS—Shirt, underwear, pajama, and other utilitarian buttons in pearl and white colors were sold in considerable volume prior to the war. Speed of molding, permanence of color and finish, and uniformity of size and shape were the selling points of such parts.
2. TABLEWARE—Although urea-formaldehyde compounds are not so water-resistant as melamine-formaldehyde types, they were sufficiently satisfactory for use in inexpensive tableware or lightweight tableware for picnic and air transport service.
3. HOUSINGS—Ivory-colored clock cases and radio cabinets consumed considerable quantities of these compounds because of their permanence of color and form.
4. PACKAGES—Decorative jewelry boxes and cosmetic containers were a large market.
5. CLOSURES—Bottle tops, particularly cosmetic, constituted a large demand.
6. LIGHTING REFLECTORS—Because of lightweight, shock resistance, and light-diffusing properties, considerable amounts were used as lighting reflectors.
7. Many miscellaneous items, such as displays, novelties, toys, etc., were produced from these materials.

WAR APPLICATION—Urea-formaldehyde molding compounds have served the war effort chiefly in the form of buttons. Soldier's uniform buttons of urea have replaced brass.

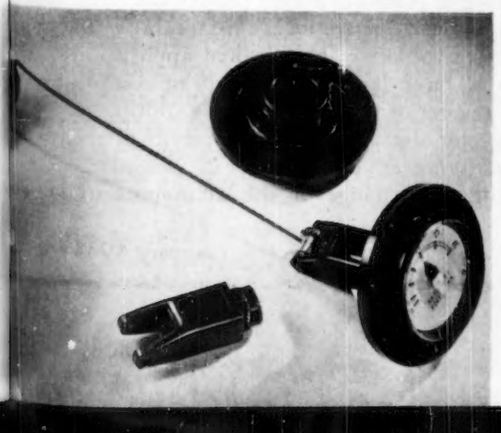
Urea-formaldehyde resins have been widely used in the form of adhesives for plywood and for waterproof corrugated and fiber containers, chiefly during wartime.

POSTWAR—The ureas should recapture many of their prewar markets. In certain instances, competition may be felt from thermoplastics, but the materials have been improved, molding methods are improving, and there should be an expanding use of ureas where color, rigidity, permanence of form and finish, lack of odor and taste are essential.

II. MELAMINE-FORMALDEHYDE resins were introduced by the American Cyanamid Company in 1939. These resins are thermosetting compounds, waterclear, and somewhat related to the urea-formaldehyde types. They differ in one respect, in that melamine resins can be combined with a greater variety of fillers, both alkaline and acid in nature, such as asbestos or glass and silica or cellulosic materials.

The melamine resin is a water clear crystalline solid, soluble and fusible. When subjected to heat or heat and pressure, it becomes a hard, insoluble, infusible material. The resin is more abrasive resistant than urea-formalde-

Two phenolic plastic parts are used in this important aircraft auxiliary gasoline gage, the top and head below.



The large curved window of an acrylate plastic extends the diver's view and reduces weight.

hyde types, more heat-resistant, and less affected by acids and alkalies or water.

Since it is a colorless resin, coloring agents may be combined with it to produce many bright, stable pastel or opaque shades similar in appearance to those of the urea compounds.

Melamine-formaldehyde began its career as a molding compound, combined with alpha cellulose pulp. In this form it was difficult to determine the difference between such material and urea molding materials. If analyzed carefully, it would be discovered that the alpha cellulose-filled melamine will absorb about one-quarter as much water, is more resistant to boiling water, is harder, more heat-resistant (210 F. against 170 F.), and more inert.

At a later date a molding compound of melamine resin and a mineral filler was introduced. This product had many unusual properties. Its heat resistance, depending on the formulation, was as high as 300 F. or 400 F. Its arc resistance (132–190 sec. A.S.T.M.), or resistance to carbonizing when exposed to an electric arc, was higher than that exhibited by any other synthetic plastic. Other electrical properties, such as track resistance and high dielectric strength, even at elevated temperature, were notable. Absorbed moisture seemed to have little effect on these properties. Associated with these characteristics were dimensional stability, hardness, and the ability to be molded around complicated inserts.

The third compound to be introduced was a chopped fabric-filled molding material. Here again the adaptability of the resin to various fillers was notable. The chopped fabric-filled compound showed high flexural strength (14,000 psi. A.S.T.M.), good heat resistance, arc resistance, hardness, and lack of flammability, making it an attractive heavy duty industrial, as well as consumer-type product.

Uses—Prewar: Alpha cellulose—Tableware and buttons.

The other two molding compounds have had only a wartime existence.

Wartime:

I. Alpha cellulose-filled melamine-formaldehyde compounds. Ivory, Pearl. A. Navy tableware; B. Army shirt or wash buttons. Note that this is the only colored plastic compound satisfactory for this application; C. Coffee maker parts.

II. Mineral-filled molding compounds. Color: opaque brown. A. Aircraft ignition parts: Distributors, distributor rotor, connector plugs, condenser housings, spark plug shields; B. Terminal blocks; C. Circuit breakers.

III. Chopped fabric-filled compound. Color: brown, white, black. A. Army mess trays—six-compartment; B. Heavy duty circuit breakers; C. Heavy duty tableware; D. Heavy duty telephones.

These molding compounds may be molded by compression methods; and in the case of the mineral and chopped fabric-filled types, transfer molding may also be used.

The properties imparted to the molding materials by the melamine resins will be detailed in the paper.

Melamine-formaldehyde resins have other uses and are notably important in the laminating industry. In combination with glass cloth, asbestos, or paper, their arc resistance and fire resistance give rise to a large demand for their use as industrial laminates.

In the consumer field such uses as table tops, wall surfaces, drain boards, and even exteriors, in decorative or colored, laminates are strong possibilities.

The resin is also used to produce baking enamels. These enamels are more heat-resistant and harder than the ureas.

Wet strength paper has been developed to an advantageous point through the use of melamine resins.

It is difficult to prognosticate on postwar uses of these compounds. Let us say that the molding material will prove to be of considerable assistance to the electrical industry because of its outstanding properties in that regard. Particularly is this true of the mineral-filled types.

The chopped fabric and alpha cellulose compounds will provide a more durable and more inert medium for the expression of consumer goods and will probably receive widespread acceptance.

Allyl Plastics

By Franklin Strain

ALLYL THERMOSETTING compounds were first introduced during 1942. In general these compounds are water insoluble liquids of low volatility. They polymerize when heated with a peroxide catalyst and are thereby transformed, first into gels and finally into insoluble, infusible, transparent solids. A significant feature of these materials is the absence of volatile by-product formation during their polymerization. This, with the capacity for a wide variation in physical properties of the final polymers, differentiates the allyl thermosetting plastics fundamentally from the older well-known thermosetting condensation materials.

The properties of the allyl compounds have led to two chief types of applications. The first is their casting in suitable molds, designed to accommodate the shrinkage occurring on polymerization, to produce colorless, transparent objects, notably cast sheets. These cast sheets possess superior optical clarity, and resistance to abrasion, solvents, to heat, and to crazing, as compared with other transparent plastics. Limitations consist of restricted formability, permitting only relatively moderate curvatures, and a tendency for notch sensitivity which, however, may be overcome by proper handling methods. Many complicated shapes may be cast directly. The second important application involves impregnation of reinforcing porous materials, particularly fibrous bases for the production of laminates by very low or contact pressure methods. This type of application is favored by the low viscosity and penetrating qualities of certain of the allyl compounds, and the absence of volatile products of polymerization, thus eliminating the necessity for application during the curing of pressures higher than of the order of zero to a few pounds per square inch. Adaptability to simplified low pressure processes has favored application to the production of large laminated objects of complicated shape, such as aircraft structures. The tailoring of the allyl compounds for alteration of the properties of the polymers also alters significant properties of the laminates. Test data correlating these changes in the laminates with

those in the cast polymers have been obtained. Combination of selected polymers with high strength fibrous reinforcing materials, such as Fiberglas, has resulted in composites superior in certain mechanical properties to the light metals and alloys.

Only applications directly related to the war effort can at present be considered due to limitations now existing upon the production of allyl alcohol, a raw material essential to the manufacture of these plastics.

(For abstract on Vinyls, see page 47)

Acrylates

By Willard F. Bartoe

THE RECENT developments in the application of acrylic resins, like those in many other materials, have been intimately associated with our war effort. However, their history proves that they are definitely not "war babies." A brief review of their salient features shows the reasons for their importance in military applications and indicates the probable trend of future developments.

The most important commercial types, from the standpoint of their use as plastics, are the esters of acrylic and methacrylic acid. Clarity combined with exceptional stability of optical, mechanical, and electrical characteristics is common to all of these resins. They are obtainable as single polymers or as copolymers having physical characteristics ranging from those of semiliquids to those of rigid solids. All these types are thermoplastic and are, therefore, well suited to stretching, forming, and molding into intricate shapes.

The production of cast polymethyl methacrylate base sheet was greatly increased in 1943 to accommodate the demands of increased aircraft production. Along with the increase in production, there has been an extension of available sizes of these sheets, particularly in thicknesses of over $^1/_4$ in. Developments in processing have also resulted in improved optical quality of these large-size sheets. Experience gained in fabricating and testing many intricate shapes has resulted in the production of improved parts for use in aircraft—improved optically and structurally.

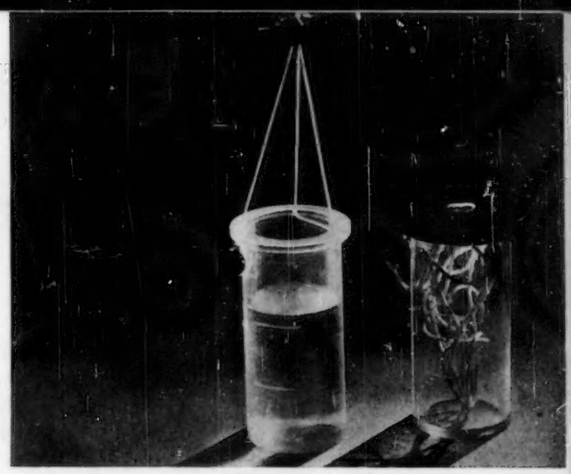
Without doubt, an extension of the knowledge gained during the present "all-out" war production activity of the manufacturers of these resins will result in their wider use as clear and colored transparent materials in many peacetime applications.

The Polystyrene Family

By W. C. Goggin

POLYSTYRENE, AS a technically important, commercial thermoplastic, has been available since about 1937. Since it was first introduced, the production of polystyrene has steadily increased. The applications of the material have been broad and varied. At the present time, due to the urgent need for styrene for the manufacture of GR-S rubber, polystyrene reaches only the military market, and then only in restricted quantities.

Within the past two years, two new materials which broaden the range of polystyrene's properties have been introduced. They are Styramic and Styraloy. The list of basic polystyrene's outstanding properties includes extremely low electrical loss, practically zero water absorption, high modulus of elasticity, good impact and tensile strength at very low temperatures, high index of refraction, and the ability to be molded at high production rates. The two materials, Styramic and Styraloy, extend this list, in the case of the former, to include flame proofness and the ability to withstand higher operating temperatures. In the case of the latter, the added properties of high elongation, high temperature stability, and extreme flexibility at very low temperatures are made available.



This polystyrene cup is used in rationing limited supply of fresh water in lifeboats, etc. The cup is tipped on its side in a tank by a small ball on the rim of the cup.

Polystyrene has been most generally fabricated by the injection molding process. In this process, it offers the advantages of high production rates, accurate reproduction of die contours, and the ability to reproduce intricate parts. It has, however, been molded by the compression process. This process is used when extremely large, heavy moldings, or great accuracy in die reproduction are desired.

Through the design of modified extrusion equipment, it has been possible to produce extruded shapes, sheets, and, more recently, film. The film is given added properties through an orienting process used subsequent to extrusion. Styraloy and Styramic can be fabricated with good results by all of the three processes.

Specifications covering standard polystyrenes and Styramic have been established by A.S.T.M. under the designation D 703 – 43 T. and various A.S.T.M. test methods appliable to rigid plastic materials are designed to evaluate the more basic properties of polystyrene and its modifications. New modifications of styrene or polystyrene

The faucets on this water bag are a vinyl plastic and the bag itself is made waterproof by a plastic coating.

The Marine insignia shown is molded from a cellulose-base plastic.

will probably further extend the diversified properties of this family, as well as make possible new fabricating procedures with the ability to fabricate much larger sizes than have been heretofore available.

Prior to the war, the most extensive use of polystyrene was in the form of injection moldings such as refrigerator parts, radio cases, salad sets, bottle tops, chemical equipment, and toilet ware. During the war, the use of polystyrene in molded form has been directed largely to electronic equipment such as radio insulators, batteries, electrical cables, coil forms, and condenser insulation. Other electronic equipment has been especially made from extruded stock and oriented polystyrene sheet.

It is believed that in the postwar era, polystyrene will be used more extensively in all of the above-mentioned applications, as well as for the production of large moldings by the low pressure, bag process. Polystyrene will very likely become an important factor in the field of coatings, impregnates, and adhesives.

Properties, Uses, and Salient Features of the Cellulose Plastics

By W. E. Gloor

Characterized by their intrinsic toughness, the cellulose plastics as a family have found increasing use during the war period for their physical properties, as well as because of their wide and easy colorability and the wide variety of workable formulations on the market. Their broad usage is exemplified with cellulose acetate, which comes into commerce in the forms of molding powders, sheets, rods,tubes, films, and foils.

Cellulose, the chief structural material of all higher plant cells, is a readily available industrial raw material in the United States. The large expansion of its uses is logical because of the present-day need which makes it more necessary than ever to apply native raw materials to their best advantage. The plastics based upon cellulose are all made from a chemical modification of the purified material, reacted and formulated into compositions which permit of ready plastic manipulation. These chemical modifications are all esters or ethers of the parent natural polymer, cellulose, since it is essentially an alcohol in its reactions. These esters—acetate, nitrate, acetate butyrate, and acetate-proprionate—and an ether—ethyl cellulose—have found many applications. The degree of substitution of the compounds may be varied, hence one finds cellulose acetate of high acetyl content being used for plastics of superior dimensional stability, along with cellulose mixed esters which are also highly substituted. In the mixed esters, the ratio of acid substituents determines the usage of the material: an ester with a ratio of about 2 acetyl to 1 butyryl finds use in films, while for hot molding plastics a material with about 2 butyryl to 1 acetyl is most often used.

All these materials are thermoplastic. The organic esters and ethers thus are readily compounded into molding powders for injection, compression, and hot extrusion molding. The inorganic nitrate ester, not readily molded by injection or compression because of its flammability, is usually shaped while containing some solvent. The materials are soluble in common solvents like alcohol or acetone: hence, they may be compounded into sheets, rods, and tubes by solvent processes, or cast into foil and film by laying their solutions, in controlled thickness, on moving bands or drums. As a class, they are largely isotropic and homogeneous, yet they show some sensitivity to changes in atmospheric temperatures and humidities, requiring careful selection if extremes of these conditions are to be withstood. As thermoplastics, they have a useful temperature "ceiling" ranging from 140 to 212 F. for various compositions. In general, the cellulose plastics comprise the cellulose derivative and plasticizers, together with dyes and pigments for color. Fillers do not play the prominent part which is theirs in the other plastics families.

Cellulose acetate, available in grades ranging from relatively soft, plastic materials to hard, dimensionally stable yet tough forms, has, in addition, outstanding solvent and oil resistance. Its inherent rigidity makes it the most widely used cellulosic sheet material, and its hardness permits its use in thin foils. Typical applications of the molded material include gas mask parts and auto and aircraft fittings, a wide variety of items of personal use, replacement plumbing fixtures, electric light bases, extruded shapes, and hardware items. Sheets go, in large volume, into aircraft and auto transparencies, safety glass interlayers, gage and dial faces, etc. Much X-ray film and protective and insulating foil also is made from this material.

Cellulose nitrate, commonly known as celluloid in its plastic form, finds use today in fountain pens, heel and seat covers, hammer heads, tool handles, battery cases, gun wadding, etc.

Cellulose acetate butyrate itself is somewhat softer than the above materials; by judicious plasticization, however, it is made into a variety of forms, hard and soft. Its chief outlet is in molding powder, which is formed into extruded shapes, such as auto and aircraft fittings, especially of larger sizes, as well as a variety of electrical and mechanical fittings. The material may be molded easily to give articles of good dimensional stability, and it is one of the best cellulose plastics for resistance to outdoor weathering.

Ethyl cellulose, the newest cellulose derivative to appear in plastic form, is outstanding for toughness (especially at low temperatures), dimensional stability, and alkali resistance. It finds wide use in electrical and mechanical applications largely confidential in nature. The canteen, resistant to freezing and boiling water, is a good example of its successful application because of these properties. Ethyl cellulose film, readily drawn cold, also finds wide use. A few special rubber-like plastics are based upon highly plasticized ethyl cellulose.

Several other new forms of cellulose plastic are being developed at present. The plastic boat, mentioned in the accounts of the Aleutian fighting, is such a development, based upon a laminated structure. Development is active in the production and use of low-cost fillers and new plasticizers. Tough sheeting with a clarity equalling that of the acrylic resins may also be expected in this field.

Mechanism of Corrosion Processes

By R. M. Burns[1]

EDITOR'S NOTE: The following two papers by Messers. Burns and Brown were presented as part of a Symposium on Corrosion featuring a meeting sponsored by the Detroit District Committee on December 9. A short news article of the meeting is in another portion of the BULLETIN.

CORROSION IS a process by means of which metals undergo chemical reactions with nonmetallic elements of their environments producing chemical compounds which are either oxides or salts. The nature of these compounds, particularly their solubilities in the surrounding medium, and the position with respect to the metal surface where they may be precipitated as solid compounds will have considerable influence upon the process and may indeed determine whether it will continue to the destruction of the metal or become stifled, providing, thereby, corrosion resistance to the metal surface. Thus it is that a knowledge of the chemistry of metals provides a foundation for corrosion engineering. The inadequacy of such knowledge for the prediction or explanation of the occurrence of corrosion in many instances arises from the fact that metals and their environments are rarely simple and homogeneous in composition or structure. Quite the contrary—in practical experience there are usually present unknown, unrecognized, and uncontrolled variables which profoundly influence, if they do not actually determine, the course of corrosion. One may seek light upon the nature of these variables in an effort to explain specific cases of corrosion and devise remedial measures. While it is usually advantageous to acquire full knowledge of all the component variables of a corroding system, even this information may not be sufficient to explain the character of the corrosive action. Thermodynamical calculation may be usefully employed to determine whether a given reaction can take place, but it is often difficult to segregate this reaction for treatment, or to identify it as the rate controlling process. Corrosion tests, valuable as they may be in furnishing general engineering information upon the corrodibility of materials, supply only the end result and do not explain how it occurred. It is information on "how it occurred" that is most needed to supplement existing knowledge derived from chemical texts and exposure tests.

ELECTROCHEMICAL NATURE OF CORROSION

Corrosion occurs by means of electrochemical reactions which are, in simple terms, electrolytic processes. It becomes profitable, therefore, to consider corrosion in the light of the operation of electrolytic cells, their anodic and cathodic reactions, and their electrolytic and electronic resistances. Observation of the characteristics of such electrolytic corrosion cells leads to an understanding of the mechanism of the action and makes possible the prediction of corrosion behavior.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 260 S. Broad St., Philadelphia 2, Pa.

[1] Assistant Chemical Director, Bell Telephone Laboratories, Inc., New York, N. Y.

First of all, for purposes of discussion it is desirable to distinguish between corrosion reactions which involve water and those which do not. The first may be said to occur by the "wet" or hydrogen replacement process in which the corroding metal replaces hydrogen from water, and the second by the dry or direct combination process as exemplified by oxidation and tarnishing reactions. When a metal corrodes by a reaction of the first type, two reactions take place simultaneously upon its surface at areas which may be contiguous but not identical; metal ions pass into solution and hydrogen ions pass out of solution. The areas at which metal dissolves are the anodes, and the areas at which hydrogen is discharged are the cathodes of electrolytic (or galvanic) corrosion cells. The existence of these cells results from a heterogeneity of the interface between metal and environment arising either from differences in composition or physical condition of the metal surface or of concentration of the environmental components. For example, the following are typical of the electrolytic cells by means of which corrosion may occur:

Anode	Cathode
Base metal	Noble metal (2 metallic phases)
Metal	Metal oxide on surface
Metal	Carbonaceous dust on surface
Strained metal	Annealed metal
Small grain size	Large grain size
Metal (absence of O_2)	Metal (O_2)
Metal in low metal ion concentration	Metal in high metal ion concentration

APPLICATION OF ELECTROMOTIVE FORCE SERIES

The basis for the electrochemical treatment of corrosion is the electromotive force series, an arrangement of the elements in order of their dissolution tendencies in solutions of their own ions of corresponding concentrations. The resulting standard potentials may be considered as the voltages of electrolytic cells in which one pole is the hydrogen electrode at one atmosphere of hydrogen gas pressure in a solution containing *in effect*[2] one atomic weight in grams of hydrogen ions in 1000 g. of water at 25 C., and arbitrarily designated as zero, and the other electrode is the metal in question in a solution of its own ions of this same concentration.

Now it may be said at once that these conditions are not realized in practical corrosion problems and that, as a consequence, the standard emf. series is not directly applicable. The standard ion concentrations and hydrogen gas pressure required in this comparison are not usually provided by nature. It is well known, however, that for every tenfold increase in the ionic concentration of a metal in its environment, the tendency of the metal to dissolve or corrode is decreased, that is, it becomes more noble by $\frac{0.059}{n}$ volt at 25 C., where n is the number of unit electrical charges on the ion or, in other words the valence of the metal. This change in potential of some of the common

[2] The more widely understood term "concentration" will be used rather than the term "activity" in dealing with ionic solutions. Actually more than one atomic weight in grams of metal is required to obtain the theoretical ionic activity of 1 g. atomic weight in 1000 g. of water. For this reason the term "in effect" is employed and will be implied later when mention is made of ionic concentration.

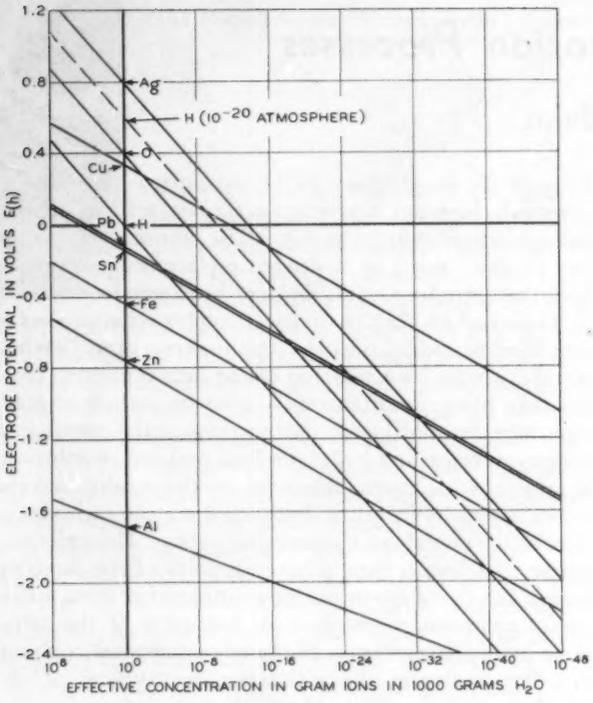


Fig. 1

metals with change in effective ion concentration is illustrated in Fig. 1. In this graph it will be observed that the ordinate corresponding to a concentration of one gram-ion (10^0) provides the usual emf. series and that at certain other concentrations the potential relationships of specific pairs of metals may be reversed. For example, it will be noted that whereas silver is more noble than (cathodic to) copper, lead, and iron in the emf. series, it is anodic to copper at ion concentrations less than 10^{-16}, anodic to lead at ion concentrations less than 10^{-32}, and anodic to iron at ion concentrations less than about 10^{-43}. This comparison is made upon the assumption that each metal in the pairs or couples considered is in equilibrium with the specified concentrations of its own ions, but this is a condition probably not attainable and certainly unlikely to occur in practical corrosion problems. In general experience the respective ion concentrations of two metals which develop upon exposure to a given environment will be quite different, with the result that the above comparisons of potentials do not hold. To illustrate this point, a couple consisting of iron and lead (which may be realized practically when lead cable sheathing comes in contact with iron or steel structures underground) may be chosen. It is known from experience that lead is the anodic or corroding element of this couple in alkaline soil waters, whereas iron is the anodic member in neutral and acid solutions. This behavior is understandable and is predictable when it is known that the concentration of ferrous ions which develops upon exposure of iron to distilled water is one gram ion per 1000 g. of water and 10^{-10} in alkaline solutions (of pH 12) whereas the concentration of lead ions which develops in distilled water is approximately 10^{-4} and in alkaline solutions is of the order of 10^{-18} or less. It will be seen from Fig. 1 that a reversal of potential of the iron-lead couple is involved in this comparison in the two environments. In actual experience the presence of oxygen renders iron somewhat more cathodic than the above theoretical values without, however, altering these potential relationships.

Aluminum from its position in the emf. series should behave anodically toward zinc; that it does not usually do so in neutral and slightly acid solutions[3] is owing to the presence of an oxide coating which is stable in these solutions and which ennobles the surface of the metal to a potential on the cathodic side of zinc.

Since the cathodic element of a corrosion cell is usually a metal acting as a hydrogen electrode it may be well to point out that its dissolution tendency depends upon the pressure of hydrogen gas at the metal surface. For every tenfold decrease in gas pressure, the potential of the resulting hydrogen electrode becomes more noble (more cathodic) by 0.029 v. In Fig. 1 the solid line representing change in hydrogen potential with change in ion concentration pertains only to the hydrogen electrode under one atmosphere of hydrogen gas pressure. At some other gas pressure, say, 10^{-20} atmosphere, the potential-ion concentration relationship becomes that represented by the broken line. The hydrogen pressures of corrosion cell cathodes may vary from almost zero to one atmosphere or more, depending upon the relative rates of hydrogen discharge and hydrogen removal at the cathode surface. The rate of discharge depends primarily upon the potential of the corrosion cell; and the rate of hydrogen removal depends upon rate of its diffusion from the cathode surface and by the rate of its reaction with oxygen which may be present. If the concentration of oxygen is more than that required to combine with all the hydrogen liberated, then the cathodic areas become in reality oxygen electrodes of still more noble potential.

From these considerations it is evident that any of the metals, including silver and copper, shown in Fig. 1 may corrode against cathodes, either hydrogen or oxygen, of potential values which are more noble than themselves.

Formation of Protective Films

During the process of corrosion the ion concentration of the corroding element or anode increases, rendering its potential position more noble, while at the same time the hydrogen ion concentration at the cathode decreases and the hydrogen gas pressure increases, both changes rendering the cathode less noble. The result is that the anodic and cathodic potentials approach each other and may become identical, whereupon corrosion ceases. More generally, however, a corrosion process ceases because the environment becomes saturated with corrosion products which, because of their limited solubilities precipitate out, forming films at the metal surface. These films may be protective in character if high in electrical resistance and if so highly insoluble as to be precipitated in close contact with the metal surface. In such a process the more anodic areas are progressively coated until eventually the entire surface is filmed over. For example, if lead cable sheathing is exposed to soil waters containing soluble silicates, it does not corrode because it becomes coated immediately with an insoluble film of a complex lead silicate which pre-

[3] R. B. Mears and H. J. Fahrney, "Cathodic Protection of Aluminum Equipment," *Transactions*, Am. Inst. Chemical Engrs., Vol. 37, p. 911 (1941).

vents corrosion. On the other hand, when lead cable sheathing is immersed in distilled water it corrodes fairly rapidly since in this case a more soluble compound is formed. When iron is immersed in water, ferrous ions enter the solution and since ferrous hydroxide is reasonably soluble these ferrous ions may migrate an appreciable distance from the anodic areas before becoming oxidized to ferric ions and being precipitated in the solution as the less soluble ferric hydroxide. Thus, the more distant position with reference to the surface at which this compound is deposited, together with its physical structure when it is formed, reduces its protective quality.

Influence of Electrode Polarization

The discussion thus far has been concerned with the origin and potentials of corrosion cells and the function of corrosion products in determining the end point of the process. It now becomes desirable to examine the reactions of corrosion cells from an electrochemical standpoint as a means of obtaining further knowledge of corrosion processes. Since the rate of corrosion is directly proportional to the current which flows in a cell in a given time the measurement of this current would provide information of great practical importance. While this has been accomplished in the laboratory[4] by careful experimentation, it is usually not feasible to isolate and measure the characteristics of individual cells by means of which metals corrode in practice. It is possible, however, to determine the relative importance of factors which promote or retard corrosion cell activity and the manner in which these influences operate. Information of this kind furnishes considerable insight into the problem of corrosion. The effect of ionic concentration changes upon corrosion cell voltage and current has been mentioned in a previous paragraph. To reiterate, it may be said that, owing to the great speed of the primary electrode reactions and the relatively slower speed of the secondary processes of diffusion and convection, metal ions accumulate at the anode making its potential more noble while hydrogen ions disappear at the cathode making its potential less noble. This difference in potential at the anode is known as anode polarization and at the cathode, as cathode polarization. These polarizations, which increase with current density, act as a counter electromotive force which opposes the initial corrosion cell voltage. It is this polarization behavior which controls the rate of corrosion since it determines the rate of current flow. The resistance of all of the common metals to corrosion in ordinary environments containing moisture can be considered in terms of anodic or cathodic polarization or of the two combined.

The measurement of polarization consists in the determination, by means of a standard reference electrode, of the change in potential with current flow of a metal when it is made the anode in one case and the cathode in another in an electrolytic cell which provides the components of a given environment. From studies of this kind upon metals in a variety of known environments it becomes possible to identify the factors which accelerate or retard corrosion cell action and to determine whether such influence is exercised upon the cathodic or anodic elements, that is, whether the corrosion process is cathodically or anodically controlled.

The identification of the electrode controlling corrosion in a given case may be made usually by direct measurement of the potential of the metal as a whole, since this will be the composite of the potentials of the corrosion cells upon its surface. The stability of this control may be judged by observation of the change of potential with time. In cathodic control the observed value of the metallic potential will be that of the anodes since the cathodes are the more highly polarized, and in anodic control the potential will be that of the cathodes since then the anodes are the more highly polarized. Thus cathodic control is indicated by an electronegative position of the potential-time curve and anodic control by a noble position of this curve.

Practical Application of Polarization Curves

The relation between potential-time curves and anodic and cathodic polarizations is shown schematically in Fig. 2.[5] Here it is indicated that the potential of iron

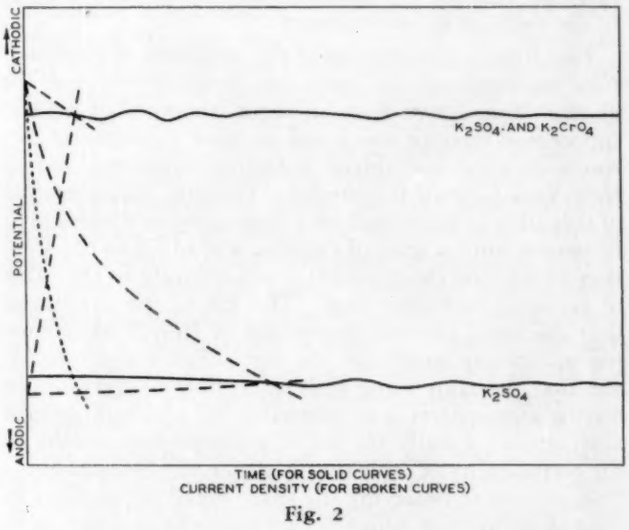


Fig. 2

with time (lower solid curve) in a common salt solution is essentially the potential of iron in this solution, the reaction being controlled by cathodic polarization. Incidentally, iron is corroding in this case at a rate not exceeding the current density corresponding to the intersection of the potential-current density curves (broken curves intersecting on lower solid curve). However, if an organic type inhibitor such as is used in pickling iron or steel were added to this solution the rate of corrosion would be reduced markedly without changing the shape or position of this potential-time curve. Observation of the cathodic polarization curve for the inhibited solution (the dotted curve in Fig. 2) discloses that the reason for the reduction of corrosion rate is the lower value of corrosion current density permitted in this case as compared with the solution which does not contain the inhibitor. To cite another example of cathodic control, cable sheathing is corroded by contact with moist coarse sand but not by contact with moist fine silt. Determination of the cathodic

[4] R. H. Brown and R. B. Mears, "The Electrochemistry of Corrosion," *Transactions*, Electrochemical Soc., Vol. 74, pp. 495–517 (1938).

[5] Courtesy of Reinhold Publishing Corp., New York, N. Y., publishers of American Chemical Society Monograph No. 79, "Protective Coatings for Metals," by R. M. Burns and A. E. Schuh.

polarization behavior in the two instances should show that a relatively high corrosion current density is realized in the first case in contrast to the highly polarized condition in the latter case.

If to the simple salt solution under consideration potassium chromate is added, the potential of iron is shifted markedly in the cathodic or noble direction owing to anodic polarization. Inspection of the iron surface exposed to this solution would show it to be passive and not corroding. The use in automobile radiators or air conditioning equipment of strong oxidants such as dichromates or of compounds which form highly insoluble compounds with iron provides corrosion resistance by anodic polarization. The passivity of nickel-chromium and other corrosion-resistant alloy steels is reflected in values of potential of the same order as is shown by ordinary steels in solutions containing dichromates. Passivity in both cases persists with time unless film-destructive agents such as chlorides are introduced into the environment. Indeed the concentration of chloride required to cause an abrupt break in passive potential gives some indication of the degree of passivity attained by introduction of the protective agent to the metal or its environment.

Two further illustrations of the usefulness of potential-time measurements in corrosion investigations may be given. Wire drawn from an ingot composed of a 50-50 copper-iron mixture was found to resist atmospheric corrosion in rural and inland industrial exposures, but in New York City air it corroded. Potential measurements of this alloy in dilute sodium sulfate solution showed it to be passive until a trace of chloride was added to the solution whereupon the potential broke abruptly to the value of active or corroding iron. This led to the conclusion that the small chloride component of New York atmosphere was responsible for the corrodibility experienced, and that the alloy being thus susceptible to corrosion in marine atmospheres was unsuitable for a certain general application. Finally the use of potential-time studies in the corrodibility of cable sheath alloys may be mentioned. This consists in observing the sharp break in potential in the noble direction which occurs upon the completion of sulfation of the alloy in sulfuric acid. The rate of sulfation determined in this manner is the rate at which a protective film forms in an environment containing a protective agent and it is related to the rate of corrosion of the alloys under corrosive conditions.

Electrolytic Nature of Oxidation and Tarnish

The discussion thus far has dealt with corrosion in the presence of moisture, a process which consists essentially in the electrolytic replacement of hydrogen ions by ions of the corroding metal. On the other hand, oxidation and tarnish reactions in gases or elemental vapors which do not contain appreciable amounts of water vapor take place by an electrolytic process which differs from the replacement process described in preceding paragraphs in that the whole metal surface acts as the anode against a cathode which initially may be considered to be a monomolecular layer of oxygen, sulfur, or other nonmetallic element in contact with the metal surface. In the operation of this electrolytic cell, metal ions and electrons leave the metal surface migrating into the metal-environment interface. The electrons ionize the nonmetallic elements, oxygen, sulfur, etc., in this interface converting them into ions, thus completing the circuit of the cell. By this process there is built up at the surface a lattice of corrosion products of the metal and nonmetal which becomes a film of increasing thickness. The process of corrosion in this case is controlled by the resistance of this structure to the diffusion of electrons or ions or to both. Higher temperatures increase the energy of these entities and permit the growth of thicker films. The physical structure and continuity of these films have an important effect upon the process and may determine whether it ceases or continues. Evidently cracks or scaling of the films as well as the electrical resistance of the film itself will determine the degree of corrosion resistance which a metal may develop in a given environment. It has been shown that the tarnishing of copper can be prevented by contriving to form a film of aluminum oxide or beryllium oxide on the surface of the metal.[6] It is believed that the effectiveness of these films, which show high electrical resistance, is due in part at least to the fact that the ions of these metals being smaller in size than the copper ion form a tight lattice or screen at the surface which restrains migration of the larger copper ion and thus prevents the growth of tarnish films.

In conclusion it may be stated that significant information upon the corrodibility of metals may be obtained by observation of their electrolytic behavior in cells in which the metals are electrodes and the components of the surrounding environment, the electrolyte. The potentials and polarization characteristics of the electrodes of these corrosion cells provide information as to corrodibility and corrosion resistance and an indication of corrosion rate.

[6] L. E. Price and G. J. Thomas, "Oxidation-Resistance in Copper Alloys," *Journal*, Inst. Metals, Vol. 63, p. 21 (1938).

Symposium on Technical Library Techniques

A number of members may be interested in a Symposium on Technical Library Techniques published in the December, 1943, issue of the *Journal of Chemical Education*. There is discussion on the importance of technical writing in chemical education which includes a most excellent bibliography of 63 references. Problems of scientific literature research, the technical library in undergraduate work, and treatment of various other problems will also be found. The use of microfilm in the research library is another of the topics covered. There is also an interesting paper dealing with company-published magazines and house organs, and discussion on literature service for fuel chemists.

This journal is the official organ of the Division of Chemical Education and the History of Chemistry of the American Chemical Society, published by the Mack Printing Co., 20th and Northampton Sts., Easton, Pa.

Research on Lead Alloys for Cable Sheathing

Recently issued by the Engineering Experiment Station, University of Illinois, is Bulletin No. 347 providing a report on Fracture and Ductility of Lead and Lead Alloys for Cable Sheathing. This work was carried out by Prof. Herbert F. Moore, Research Professor of Engineering Materials, and Curtis W. Dollins, Engineer of Tests, Investigation of Lead Sheath Materials, in cooperation with the Utilities Research Commission. Topics covered in detail include tensile strength and ductility, correlation between bursting tests, effect of notches, effect of greasing lead sheathing metal, fatigue strength and other miscellaneous studies. Copy of the 64-page report can be obtained from the University of Illinois, Urbana, Ill., at 70 cents each.

Galvanic Corrosion

R. H. Brown[1]

Designers of structures and equipment have available alloys possessing a wide variety of properties. These materials are employed according to the requirements of the various parts of the assembly. However, the alloys are chosen usually because of their physical properties such as tensile strength, yield strength, elongation, resistance to impact, fatigue strength, thermal conductivity, electrical resistance, casting or forming characteristics, and thermal expansion. Unfortunately, far too infrequently the designers have not considered the chemical properties of the alloys and the effects on their corrosion behavior by contact of certain alloys.

The electrochemical character of normal corrosion (that is, the corrosion of single specimens) has been demonstrated for several metals (*1–4*).[2] It has long been known that the corrosion of a metal is accelerated by contact with some metals and is reduced by contact with certain other metals (*5*, *6*). This behavior is also the result of an electrochemical mechanism and has been termed "galvanic corrosion." The total weight loss of an anodic electrode of a couple, if the mechanism is entirely electrochemical, is directly proportional to the current flowing from the anode areas to the cathode areas. The total current causing the corrosion is the sum of the current flowing from anodes to cathodes of the local cells on the anode electrode and the current flowing from the anode electrode to the cathode electrode. In Fig. 1 the current flowing in the local cells on anode metal is shown by I_L, and that flowing from the anode metal to the cathode metal by I_G. The extent of galvanic corrosion current (that is, galvanic corrosion) is dependent on many factors, among which are potential difference, polarization, current distribution, resistance of both the corrosive environment and the metallic circuit, etc.

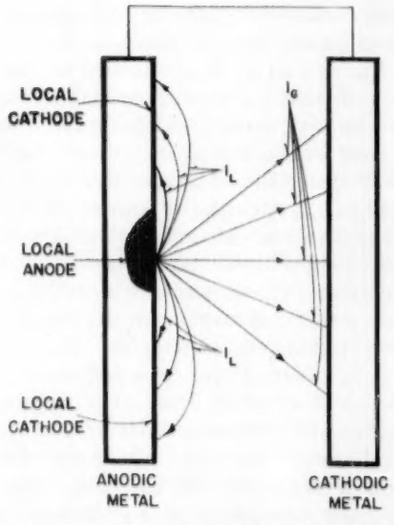


Fig. 1.—The Division of the Corrosion Currents Flowing from the Anode Areas to the Local Cathode Areas on the Anodic Metal and to the Cathodic Metal of the Couple.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 260 S. Broad St., Philadelphia, 2, Pa.

[1] Chemical Metallurgy Div., Aluminum Research Labs., Aluminum Company of America, New Kensington, Pa.

[2] The italic numbers in parentheses refer to the reports and papers appearing in the list of references appended to this paper.

Potential Differences

In an attempt to predict the behavior of one metal in contact with another, the electrochemical series has been employed. The metals are arranged in the electrochemical series according to the potentials of the metals in solutions containing ions of the respective metals at thermodynamic concentrations of unity. Consequently, the electrochemical series cannot be employed even to predict the potential differences between metals in the general case, let alone the amount of acceleration of corrosion resulting from the contact of the two metals. However, the potentials measured in the corrosive environment determine which of two metals will be anodic and which cathodic.

In Table I are listed the potentials, as measured against a 0.1 *N* calomel electrode, of magnesium, aluminum, zinc, iron, and copper in several solutions (*7–11*).[3] Air was permitted to diffuse into the solutions under quiescent conditions during the measurements. All the specimens were abraded with emery cloth (Aloxite 120). The potentials listed in Table I show how, in many cases, the composition of the solution determines which of two metals of a couple would be anodic. Further, the measured potentials for this series of metals are not in the same order as arranged in the electrochemical series.

However, potential measurements can only predict which of two metals will be anodic and which cathodic. In order to estimate the extent of galvanic corrosion caused by the contact of two metals, consideration of other factors such as polarization must be taken into account.

Effects of Polarization and Resistance

From the electrochemical theory of corrosion the over-all corrosion reaction (for divalent metal)

$$M + 2H^+ = M^{++} + H_2 \quad \ldots\ldots\ldots\ldots (1)$$

is divided into two reactions which occur at areas separated by some finite distance. The reaction occurring at an anodic area is

$$M = M^{++} + 2_e \quad \ldots\ldots\ldots\ldots\ldots (2)$$

and that occurring at cathodic areas is

$$2H^+ + 2_e = H_2 \quad \ldots\ldots\ldots\ldots\ldots (3)$$

The reactions and their rates occurring at either area or both areas control the rate at which the over-all reaction proceeds. An alteration of the rate of the reaction at either electrode may result in a change in the potential of the electrode.

[3] Numerous other tables of irreversible potentials have been published.

TABLE I.—POTENTIAL OF METALS IN SEVERAL SOLUTIONS 0.1 *N* CALOMEL SCALE.

Solution	Magnesium		Aluminum		Zinc		Iron		Copper	
	Initial	Steady	Initial	Steady	Initial	Steady	Initial	Steady	Initial	Steady
Electrochemical series	−2.68	−2.68	−2.01	−2.01	−1.10	−1.10	−0.78[a]	−0.78[a]	+0.18[c]	+0.18[c]
							−0.37[b]	−0.37[b]	+0.01[d]	+0.01[d]
1 *M* NaCl	−1.75	−1.72	−1.03	−0.86	−1.15	−1.15	−0.79	−0.80	−0.33	−0.35
1 *M* Na_2SO_4	−1.75	−1.75	−1.10	−0.50	−1.18	−1.19	−0.84	−0.84	−0.31	−0.14
1 *M* Na_2CrO_4	−1.22	−0.96	−0.92	−0.71	−1.11	−0.67	−0.31	−0.16	−0.18	−0.13
1 *M* HCl	−1.78	−1.68	−0.81	−0.80	−1.12	−1.14	−0.65	−0.66	−0.24	−0.20
1 *M* HNO_3	−1.49	−1.49	−0.74	−0.49	−1.06	−1.06	−0.43	−0.58	−0.15	−0.12
1 *M* NaOH	−1.61	−1.47	−1.62	−1.50	−1.53	−1.51	−0.47	−0.22	−0.45	−0.35
1 *M* NH_4OH	−1.50	−1.43	−1.43	−0.80	−1.47	−1.50	−0.37	−0.18	−0.62	−0.53

[a] Ferrous ion. [b] Ferric ion. [c] Cuprous ion. [d] Cupric ion.

This variation of potentials of the electrodes with the current density on them is known as polarization. As the current is increased, the potential of the anode becomes more cathodic and the potential of the cathode becomes more anodic.

The fact that the corrosion of iron in sea water is accelerated by contact with copper is well known. Potential measurements (for example, see Table I), show that iron is anodic to copper. Evans (*11*) has exposed steel specimens 2.5 cm. wide partially immersed for a depth of 4 cm. in a 0.1 *N* sodium chloride solution. Similar specimens of steel were exposed when coupled to specimens

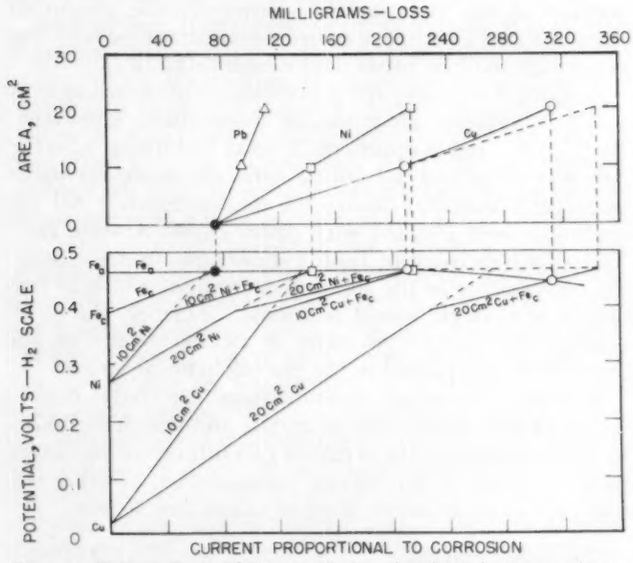


Fig. 2.—Upper Part of Chart Shows the Weight Loss of Iron Specimens After 14 Days' Exposure by Partial Immersion, Coupled to Either Lead, Nickel, or Copper (U. R. Evans).

The iron specimens were 2.5 cm. wide and were immersed for a depth of 4 cm., whereas the other specimens of the couple were the same width, or were 5 cm. wide, and all were immersed for a depth of 4 cm.

The relationship between weight loss, potential, and the polarization characteristics of the metals are indicated schematically on this chart.

of two sizes of either lead, or nickel, or copper. These latter specimens were either 2.5 cm. or 5 cm. wide and were immersed for a depth of 4 cm. The weight losses after 14 days' exposure are plotted in Fig. 2. At the lower portion of Fig. 2 the manner in which polarization affects the weight losses is explained. Since the corrosion is proportional to the current entering the solution from the anode, the current scale on the polarization diagram is proportional to the weight losses. The potential scale was developed approximately using the values of potential obtained under similar conditions of exposure (*12*). The open-circuit potentials of the local anode and the local cathode areas on the anode electrode (iron) were also taken from the literature as well as the fact that polarization of the anodic areas of iron in chloride solutions is very small and that the polarization of the cathode areas of iron is marked (3). The current resulting from the normal corrosion of this size specimen is shown by the intersection of the anodic and cathodic polarization curves Fe_a and Fe_c, and the normal (uncoupled) corrosion losses are proportional to this value.

When the specimen of copper was 2.5 cm. wide and immersed for a depth of 4 cm., the cathodic polarization curve is given by the curve "10 sq. cm. Cu." The intersection of this curve with curve Fe_a gives the galvanic corrosion current which is proportional to the galvanic corrosion. If the current density is more than sufficient to polarize the copper cathodically to more anodic potentials than the open circuit potential of the local cathodes (Fe_c) on the iron electrode, the total cathodic polarization curve for potentials more anodic than that of local cathodes on the iron electrode will be the sum of the cathodic polarization curves for the copper electrode and local cathodic areas on the iron electrode[4] or the curve marked "10 sq. cm. Cu + Fe_c" in Fig. 1. The total anodic current will be the intersection of this curve with the anodic polarization curve "Fe_a" of the anodes on the iron electrode. Similar treatment is shown for the iron-nickel couple of electrodes of equal area. Doubling the area of nickel will cause the slope of the polarization curve "20 sq. cm. Ni" to be half of that indicated for the curve "10 sq. cm. Ni." By adding these polarization curves to the polarization curve of cathodic areas on the iron electrode, the total cathodic polarization curves for these two couples can be obtained. The intersection of these curves with the polarization curves of anodes on the iron electrode give the total corrosion currents and will be proportional to the weight loss. Consequently, if the assumptions on the basis of the weight loss of the 10 sq. cm. nickel cathode were essentially correct for the construction of its polarization diagram, decreasing the slope by one half should give the polarization curve and the corrosion current for the large cathode. Since the weight losses are proportional to these corrosion currents then the corrosion current should be in the same ratio as the weight losses. Examination of Fig. 2 reveals the correctness of the assumptions. The same procedure for the lead cathode will also reveal the correctness of the assumptions, but is not included on the diagram for the sake of simplicity. However, if the anodic areas on the iron anode polarize appreciably at higher current densities, then the weight loss cannot be predicted unless the anodic polarization can be experimentally established for these higher current densi-

[4] The fact that the polarization curves may be added has been justified by experiment (see reference (*20*)).

ties. Apparently, some anodic polarization at the higher current densities occurs and the conditions are such as shown in Fig. 2.

Types of Control

Since in the previous discussion the cathodic polarization controlled the rate of corrosion, the couple is said to be corroding under cathodic control (*12, 13*). Under these conditions, the galvanic corrosion increases are proportional to the increases in area of the cathodic contacting metal.

Figure 3 shows polarization curves for several metals in a quiescent saturated sodium chloride solution open to the air, and their relationships to the short-circuited current of several couples. Under these conditions, the zinc-copper couple corrodes under practically ideal cathodic control. Consequently, the galvanic current will be proportional to the area of copper. Since the galvanic corrosion will be proportional to the galvanic current, the galvanic corrosion should be proportional to the area of the copper electrode. Akimow and his colleagues showed that the corrosion of zinc-copper couples in sodium chloride solutions is independent of the area of zinc and is proportional to the area of copper (*14*). This behavior would be expected from the polarization diagram.

Whitman and Russell (*15*) have shown under some conditions that the corrosion rates of a steel specimen and of a similar steel specimen of the same area with 75 per cent of the area coated with copper were the same. The corrosion rate was controlled by the rate at which oxygen could be supplied to the cathode surfaces ("oxygen starvation") and hence could be a specialized form of cathodic control.

From the polarization diagrams for the zinc-cadmium and zinc-tin couples in saturated sodium chloride as shown in Fig. 3, it would be expected that they would show the same behavior as the zinc-copper couple. The galvanic corrosion of the zinc would be proportional to the area of the cadmium or tin.

The tin of the tin-copper couple in saturated sodium chloride solution shows some anodic polarization. The weight loss of the tin, although increasing with increasing area of the copper, will not be directly proportional. The area of the anode as well as the area of the cathode will control the total weight loss of the tin. In Fig. 2, the iron of the iron-copper couple with the largest area of copper (20 sq. cm.) had polarized some and hence the weight loss was somewhat less than would be predicted from conditions of ideal cathodic control. This condition has been termed *mixed control*.

Under some conditions it is possible for only the anode to polarize with no polarization of the cathode and the couple is said to be corroding under ideal anodic control. The total weight loss will be proportional to the anodic area. Couples under anodic control are approached under some conditions where the anode area is small compared to the cathode area (*16*).

If neither electrode polarizes appreciably, the corrosion current, and hence the corrosion rate, is controlled by the ohmic resistances of the liquid and metallic circuits (*12, 13, 17*). Figure 4 shows a couple corroding under resistance control. A zinc electrode 33 sq. cm. in area was immersed in a solution of 0.01 *N* zinc sulfate and a copper electrode of the same area was immersed in a solution of

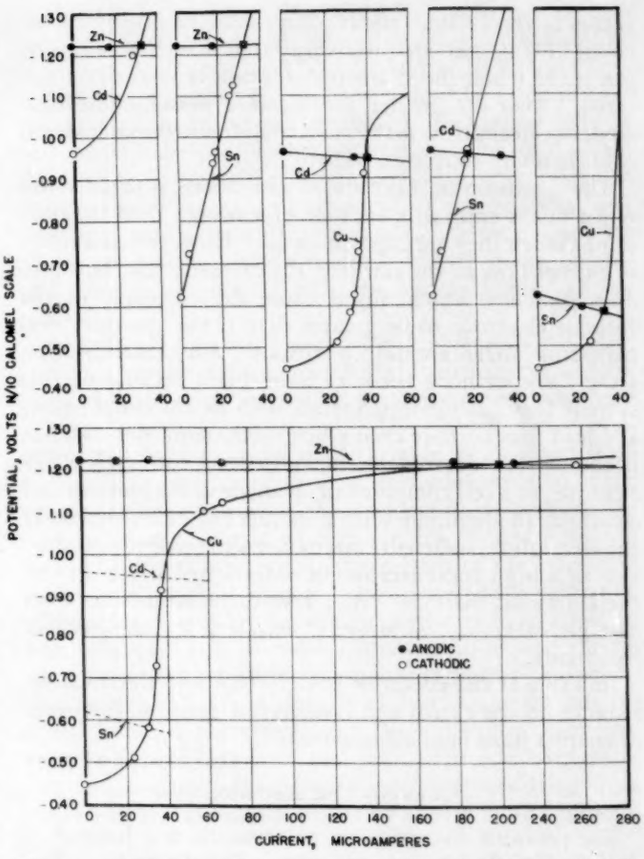


Fig. 3.—Polarization Curves for Some Couples (Area of Each Electrode 16.5 sq. cm.). Totally Immersed in Saturated Sodium Chloride.

The intersection of the anodic and cathodic polarization curves indicates the maximum current that could be generated in these couples. The solid square symbol indicates the currents that were measured at short circuit.

0.01 *N* copper sulfate. The two solutions were separated by cellophane membrane. The polarization of either electrode was slight. At short circuit, the main resistance to current flow was the resistance of the electrolyte. The *IR* drop through the electrolyte increases linearly with increasing current. Even in some cases where the polari-

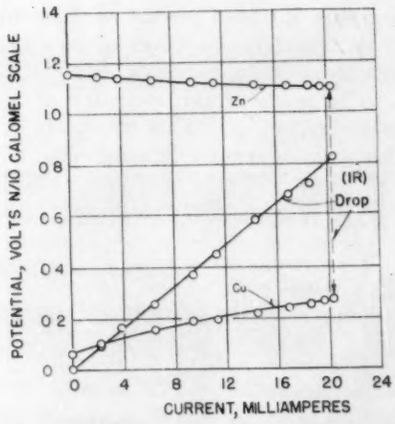


Fig. 4.—The Potential and Current Relationship of a Cell Corroding Under Resistance Control.

The electrodes were immersed in 0.1 *N* sulfate solutions of the respective metal ions.

zation is appreciable, the *IR* drops must be taken into account (*17*) if they are relatively large. Such a condition can occur when the corrosive solution is vigorously agitated. Also the greater the distance between the electrodes in an electrolyte the more completely the couple will corrode under resistance control.

The corrosion of most alloys and metals is usually less when functioning as a cathode of a couple than that obtained when they are exposed alone. However, as a result of current flow to the cathode, the cathodic reactions produce products which might cause the corrosion of the cathode electrode to be greater than if the specimen was corroding under normal conditions. Since the solution around the cathode becomes more basic because of this current flow, amphoteric metals such as aluminum, zinc, and lead may corrode even when functioning as a cathode if the current density on the cathode is too high. For example, in a cell composed of an anode of magnesium and a cathode of aluminum with a sodium chloride solution as the electrolyte, sufficient current flows to cause the production of a high concentration of sodium hydroxide around the aluminum cathode. As a result, the aluminum, even though cathodic, is severely attacked by the sodium hydroxide.

In Table II the effects of polarization and electrical resistance on the extent and intensity of galvanic corrosion of couples have been summarized.

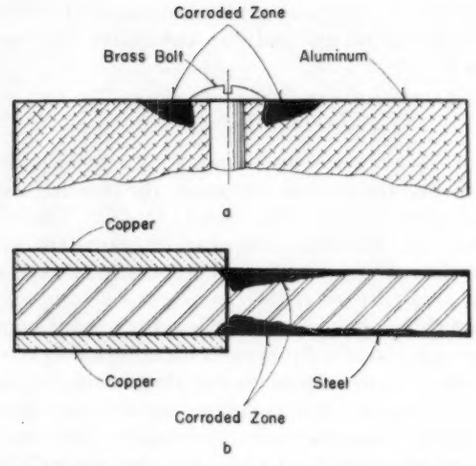


Fig. 5.—The Manner in Which Corrosion Is Distributed in Certain Types of Couples Encountered in Service.

Current Distribution

The previous discussion on polarization was limited to straight line flow between plain parallel electrodes. The geometric shape and position of the metals are very important in determining the intensity and distribution of corrosive currents. Two examples are sketched in cross-section in Fig. 5. The corrosion of aluminum around a brass bolt or of steel on a partially copper-plated piece of steel will be more intense adjacent to brass or copper and will become less intense the greater the distance from the cathodic area. Consequently, the anodic current density would be highest adjacent to the cathode and would decrease the greater the distance from the cathode area. Also the greater the resistance of the electrolyte the more localized will be the corrosion of the anode adjacent to the cathode area. The distribution of current for unsymmetrical electrodes has been treated mathematically (*18*). For certain combinations of different-shape electrodes, the current distribution can be calculated. Such data enable predictions to be made of the intensity of attack on a limited number of couples. This information, although of great value, cannot readily be employed in discussing

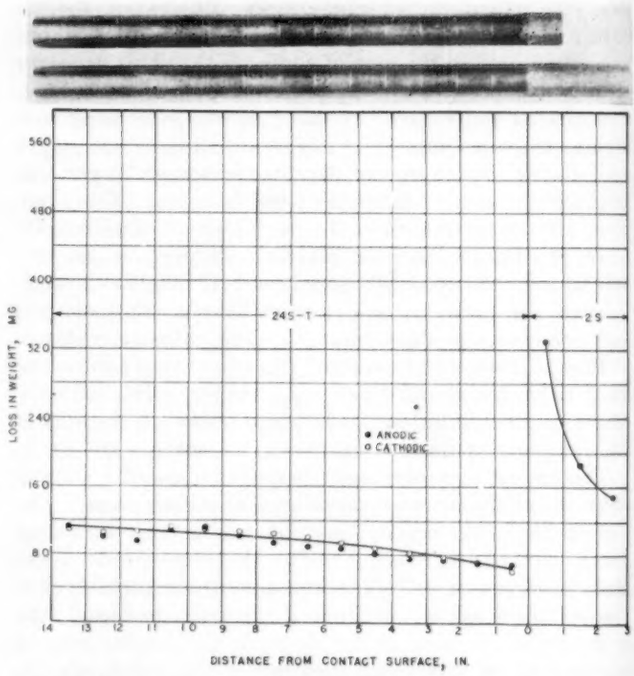


Fig. 6.—Examples of a Corrosion Couple Where the Current Density Would not Be Uniform Either on the Anode or Cathode Areas.

The couples were made up of 1-in. lengths of 1-in. diameter 24S-T and 2S-$^1/_4$H.

TABLE II.—EFFECT OF POLARIZATION AND RESISTANCE ON THE GALVANIC CORROSION OF COUPLES.

Type of Control	Polarized Electrode	Effect of Increasing Anode Area[a]		Effect of Increasing Cathode Area[b]		Example
		Total Weight Loss of Anode	Intensity of Anodic Corrosion	Total Weight Loss of Anode	Intensity of Anodic Corrosion	
Cathodic	Cathode	No effect	Decreased	Increased	Increased	Zn-Fe and Zn-Cu in neutral chloride solutions.
O_2-starvation	Cathode	No effect	Decreased	No effect	No effect	Total immersion of Fe-Cu in solutions of restricted liquid-air interface.
Mixed	Both	Increased	Decreased	Increased	Increased	Fe-Cu in neutral salt solutions.
Anodic	Anode	Increased	No effect	No effect	No effect	Al-Cu in neutral chromate solutions.
Resistance	Not appreciable	Depends upon effect of area of electrode on ohmic resistance. Decrease in resistance will increase total weight loss.				Most metal combinations in distilled water.

[a] Cathode area constant.
[b] Anode area constant.

the galvanic current between metal combinations encountered in equipment, especially where polarization becomes important.

An example of a corrosion couple where the current density would not be uniform, either on the anode or cathode, is shown in Fig. 6. These couples were prepared by joining fourteen 1-in. long sections of 1-in. diameter 24S-T alloy rod[5] to either one 1-in. length of 1-in. diameter 2S-1/4H rod,[6] or to three 1-in. lengths of the 2S-1/4H rod. The 2S-1/4H is anodic to 24S-T by about 0.16 v. in a neutral chloride solution. After weighing each section of the rods and assembling, the specimens were exposed to a forced aerated 3 1/2 per cent sodium chloride solution for 2 weeks. The rods were then removed from test, disassembled, the corrosion products removed by immersion in concentrated nitric acid, and the loss in weight determined on each 1-in. section of the rods. In this way the average weight loss of each 1-in. section was determined as a function of the distance from the contact of the 2S-1/4H with the 24S-T. These data are shown in the graph of Fig. 6. It is evident that the weight loss on the 2S-1/4H decreased as the distance from the 24S-T became greater.

Another method (*6*) has been employed where the potential difference is measured at a number of points in the solution, using two reference electrodes for this purpose. In this way the equipotential lines from the surface can be mapped and current flowing estimated from the potential gradient and the specific conductivity of the solution. This method has been very successfully applied in the case of an iron-nickel couple (*19*).

Alleviation of Galvanic Corrosion

The effects of galvanic corrosion can be alleviated by:

1. More careful selection of alloys.
2. Insulation of contacting alloys.
3. Painting.
4. Cathodic protection.

In many cases metals of satisfactory physical properties which also have compatible electrochemical properties can be selected so as to greatly minimize, or even eliminate, galvanic attack. If, in order to obtain materials of satisfactory physical properties, it is necessary to employ metals having incompatible chemical properties, sometimes it is possible to design so that the area of cathodic alloy is small and the area of anodic metal is as large as possible.

Sometimes it is possible to insulate two alloys in a structure in order to prevent their contact. This method, when it can be employed, is usually effective in preventing galvanic corrosion. However, under some conditions the products of normal corrosion of one of the metals may be washed onto the other metal or enter the solution and consequently come in contact with the other metal. These products can stimulate corrosion either by the formation of oxygen concentration cells on the metal, or by being reduced, forming minute galvanic cells on the surface of the second metal.

Painting greatly increases the resistance of the electrical circuit of the couple. Obviously, if conditions permit, both the anodic and cathodic alloys should be painted. However, if only one metal can be painted, it would be expected that painting the cathode would be a better procedure than painting the anode. If the anode only is painted and the coating breaks down at the local areas, then the same amount of attack could be concentrated in these areas, whereas if not painted, it might spread out over the entire area of the anode. Hence, painting of the anode alone might result in highly intensified attack especially under conditions approaching cathodic control.

By utilizing the ideas presented under previous headings, galvanic corrosion can sometimes be made to serve a useful purpose and when employed in this manner has been termed "cathodic protection" (*20–23*). If both electrodes of a couple can be made cathode by a current from some other source, in many cases galvanic corrosion of the couple can be prevented. The source of the current may be from an inert electrode with externally applied potential or from a metal more anodic than both of the two comprising the couple. Figure 7 shows specimens composed of 6-in. lengths of 1-in. diameter copper rods attached to 3-in. lengths of 1-in. diameter aluminum alloy rod (53S-T)[7] after 3 months' total immersion in sea water. One of the specimens had a 1/4-in. length of 1-in. diameter zinc inserted between the copper and the aluminum alloy and another a 1-in. length of zinc rod. The effectiveness of zinc in preventing the galvanic corrosion resulting from contact of the aluminum is clearly shown in the illustration.

Another example of the useful application of galvanic corrosion, that is, cathodic protection, is the coating of a metal with another metal or alloy more anodic than the basis metal. Galvanized iron, tin-coated copper, and Alclad aluminum alloys (*24*) are examples of such products. The value of the useful application of galvanic corrosion can be seen from Fig. 8. The specimens in this figure are riveted joints of 17S-T and Alclad 17S-T joined by 17S-T rivets. The alloy 17S-T[8] is an aluminum-copper alloy,

[5] Aluminum alloy nominal composition: 4.5 per cent copper, 0.6 per cent manganese, and 1.5 per cent magnesium.

[6] Commercial aluminum.

[7] Aluminum alloy nominal composition: 0.7 per cent silicon, 1.3 per cent magnesium, 0.25 per cent chromium.

[8] Aluminum alloy nominal composition: 4.0 per cent chromium, 0.5 per cent manganese, 0.5 per cent magnesium.

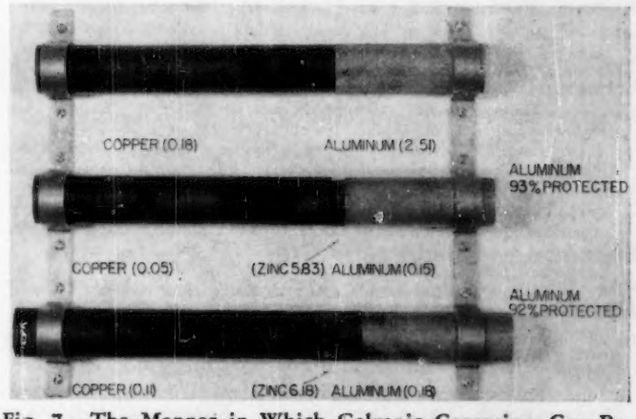


Fig. 7.—The Manner in Which Galvanic Corrosion Can Be Prevented by Cathodic Protection.

The specimens were made up from 1-in. diameter rods of copper, 53S-T, and zinc. They were exposed three months totally immersed in sea water. Figures below sections of rods denote loss in weight in grams.

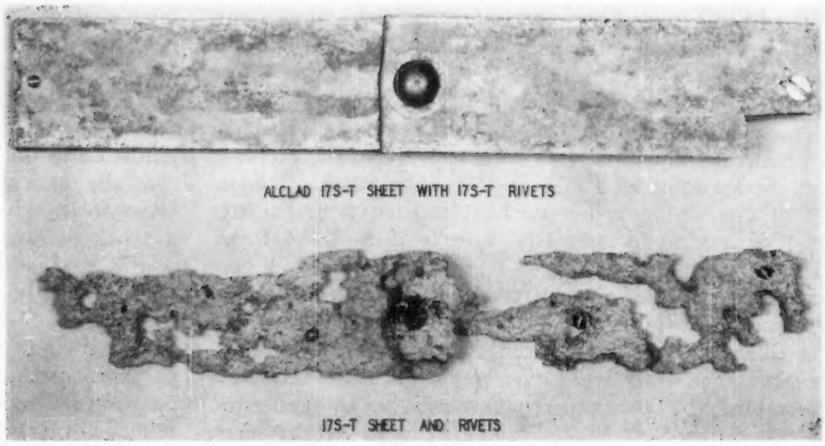


Fig. 8.—The Condition of Riveted Joints of 17S-T and Alclad 17S-T After 12-yr. Exposure to the 20 Per Cent Continuous Sodium Chloride Spray.

and Alclad 17S-T is the same alloy with a coating on both sides of aluminum of $5^1/_2$ per cent the thickness of the sheet. The aluminum coating of the alclad material is anodic to the 17S-T alloy by about 0.16 v. Figure 8 shows these specimens after they were exposed to the 20 per cent sodium chloride continuous spray. Not only has the aluminum coating electrochemically protected the basis metal, but also the 17S-T rivet. The specimen without the coating has been largely destroyed by corrosive action.

Acknowledgment:

The guidance and encouragement of E. H. Dix, Jr., and R. B. Mears, of the Aluminum Research Laboratories, are gratefully acknowledged. Also, much data presented in this paper were obtained by E. Wayne Everhart and H. C. Green, of these Laboratories.

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Building Codes—An Essential Tool

Building Codes—An Essential Tool in Urban Development is the title of an interesting booklet issued by the Construction and Civic Development Department of the U. S. Chamber of Commerce, as prepared by George N. Thompson, Chief, Building Codes Section of the National Bureau of Standards, Washington. The discussion is extremely pertinent at this time, and would repay reading time by any engineer, whether directly concerned with building code work or not.

Mr. Thompson, a member of A.S.T.M. and an authority in his field, traces the development and importance of building code departments, then relates codes to public safety and blighted areas. He points out that the redevelopments of blighted areas requires greater code flexibility, and that coordination of interrelated codes is most important. Finally, he covers the responsibilities created by war, stating that with the return of peace we must appraise innovations caused by the necessity, for example, of having large, undivided areas in hastily constructed buildings, high stresses in certain materials and related conditions. Undoubtedly, the building code deserves a greater amount of credit than is generally accorded. He concludes, ". . . whenever the code is so devised and applied that people can go about their daily affairs secure in the knowledge that their safety is adequately assured, then a contribution has been made to urban life that deserves full recognition."

Discussion of Paper on Effects of Minor Alloying Elements on Aluminum Casting Alloys[1]

Submitted by George F. Comstock:[2]

The article by Mr. Bonsack on Aluminum-Silicon Alloys in the October BULLETIN is of special interest to us because of his discussion of titanium and of alloy O of group 8 which was developed in our laboratory. While the article in general seems to be an excellent one, there are a few statements regarding titanium and alloy O that are not in agreement with our experience. One of these is the sentence near the bottom of page 47 stating that the effect of titanium "is lost during the melting of the ingot." It must be admitted that this may happen, if the precautions outlined in the excellent third subsequent paragraph are not observed properly in melting or pouring. But general experience, according to what we have found and heard elsewhere, indicates that the grain-refining effect of titanium is seldom lost but carries through at least to some extent on remelting. For instance, in five or six remeltings of aluminum-zinc-magnesium alloys similar to alloy O in containing about 0.15 per cent titanium, the only element requiring replacement to maintain the grain size and properties was found to be magnesium, the effect of the titanium remaining constant.

The limitation of the titanium content to 0.2 per cent, which Mr. Bonsack says is justified, is probably unnecessary, since in ordinary aluminum casting practice with usual pouring temperatures this will take care of itself, more than about 0.25 per cent titanium being insoluble and remaining with the dross in the melting pot. It is possible that the infusible titanium compound needles if present in excessive amounts might segregate as is stated, but this should not happen unless the alloy is overheated in melting, so that too much titanium is dissolved, and then allowed to stand before pouring, so that too-coarse crystals are formed. The only reference given to such segregation is from some Japanese work, which is well known to be sometimes quite unreliable.

It would be interesting to know how much experience is summarized in Table XIV, indicating a reduction in tensile properties due to the addition of titanium to an alloy with a high iron content. Evidence of a contrary action of titanium has been published in the *Journal*, Inst. Metals, Vol. LX, p. 106 (1937), and in Table 2 of U. S. Patent No. 2,146,330, p. 2 (1939). In the former reference, raising the titanium content of an aluminum alloy containing 7.46 per cent copper, 0.3 per cent iron, and 0.2 per cent silicon from 0.015 per cent to 0.18 per cent gave about the best strength, ductility, and grain size, and all these properties remained practically constant with 0.22 or 0.24 per cent titanium. In the latter, 0.15 per cent titanium in an aluminum alloy containing 10 per cent zinc and 0.5 per cent chromium gave the best properties, with only slight falling off, to values still much better than those of the nontitanium alloy, with titanium up to 0.26 per cent. Possibly the amount of data represented by the author's Table XIV may be sufficient to establish a different effect of higher titanium in aluminum-silicon alloys of high iron content, but in view of the opposite evidence here presented, that has been overlooked by him, the general conclusions Nos. 1 and 2 near the middle of page 48, referring to the "deleterious" effect of titanium, seem to require more careful qualification or correction.

Finally, our experience with aluminum-zinc-magnesium alloys similar to alloy O, and reports received of the experience of others also, indicate quite definitely that Mr. Bonsack is mistaken in considering more than a very low copper content desirable. It has been found that even as little as 1 to 2 per cent copper does not increase the strength, decreases the ductility, and impairs the corrosion resistance, so that copper should be kept quite low in this particular alloy. Possibly the specification limit of 0.2 per cent maximum may be a little too strict for commercial expediency under present conditions, and 0.5 per cent might be more reasonable, but the maximum of 1.5 per cent copper proposed by Mr. Bonsack is definitely too high when the best ductility and corrosion resistance are required.

Submitted by Hiram Brown:[3]

Mr. Bonsack's paper has been read with a great deal of interest. The paper indicates that a great deal of work must have been done by the author in a field which is of paramount importance today.

Since the Society has asked for discussions of the paper, there are several parts of it which I feel are worthy of further discussion, and at this time I am taking the opportunity to present written comments.

In the paper the statement was made that the modification, or grain refining property, of titanium seldom carries over from the ingot to the castings, and that it is lost during the melting of the ingot. We use a great deal of alloy O (AN-A-17; 46A1, Class 1) in our foundry. This metal is furnished to us in ingots which contain the specified alloying elements, including titanium. We make no addition of titanium after melting the ingot to pour castings, nor have others using this alloy found it necessary to do so, and yet the castings have a fine-grain structure.

As a result of Mr. Bonsack's statement, we investigated this matter a little further. Using all virgin metals, a heat was mixed containing 5.77 per cent zinc and 0.55 per cent magnesium. The titanium was left out to see what the effect on grain size would be. Since chromium is also thought to refine grain size, that too was omitted.

Test bars were poured from the heat made without titanium. To the metal remaining in the pot 6 per cent titanium-aluminum alloy was added and more test bars

[1] W. Bonsack, "Effects of Minor Alloying Elements on Aluminum Casting Alloys," ASTM BULLETIN No. 117, August, 1942, p. 45; "Part II—Aluminum-Silicon Alloys," ASTM BULLETIN No. 124, October, 1943, p. 41.

[2] Metallurgist, Titanium Alloy Manufacturing Co., Niagara Falls, N. Y.

[3] Metallurgist, Frontier Bronze Corp., Niagara Falls, N. Y.

poured. The remaining metal was then poured into ingot molds and allowed to cool. When cool, the metal was remelted and a third set of test bars poured, and the remaining metal poured in ingot molds and allowed to cool. When cool, the ingots were remelted again and a fourth set of test bars poured. All test bars in the experiment were poured at 1350 F.

A sample was taken from a test bar representing each of the four melts outlined above. These samples were polished, etched, and examined for grain size. It was found that the first heat containing no titanium was in itself fine grained, which indicates the inherent grain fineness of this type of alloy. The second heat to which the ladle addition of titanium was made, was very fine grained, finer by far than any of the other samples. The third and fourth heats, representing the remelt heats, were slightly finer grained than the heat without titanium, but coarser than the heat to which the ladle addition of titanium had been made. The remelt heats showed a more uniform grain size than did the heat without any titanium, although the average grain sizes were very nearly the same. There was little to choose between the third and fourth remelt heats in so far as grain size was concerned.

We have found in practice that the grain size of our castings, even when made from 100 per cent remelt, very closely approximates the grain size shown by the two remelt samples in this experiment, and unless the metal has been badly overheated we seldom find the grain size to be any coarser.

There is no doubt that the ladle addition of titanium greatly refined the grain size and that part of this grain refining property did not carry over into the remelt heats. On the other hand, we found that titanium was definitely beneficial in improving the physical properties of the alloy.

By referring to the accompanying Table I, it can be seen that the tensile strength and the elongation both increased when the titanium was added. The elongation of the fourth remelt heat was still superior to that of the heat containing no titanium. The physical properties of the remelt heats were both lower than that of the heat without titanium. This was due to the fact that there was a melting loss of zinc and magnesium from the heats, and since these two elements are the primary strengthening elements of the alloy, a loss of either would be expected to reduce the tensile properties. No magnesium or zinc additions were made since it was desired to eliminate any possible source of grain refinement whatever.

The loss of zinc and magnesium is shown in the accompanying Table II.

It should be noticed that the physical properties given in the accompanying Table I are lower than those required by specifications for this alloy. We believe that this is due to the fact that chromium has been omitted from the heats, since chromium is usually a strengthening element in this alloy as well as helping the corrosion resistance.

In general, the conclusions from this experiment may be stated as follows:

1. The greatest grain refinement resulted from the ladle addition of titanium.

TABLE I.—ALL BARS GIVEN ACCELERATED AGING TREATMENT.

Heat	Composition	Yield Strength, psi.	Tensile Strength, psi.	Elongation, per cent
C169...	No titanium	25 800	28 900	3.0
C170...	Ladle addition of titanium	33 950	30 600	4.5
C171...	Remelt	21 400	27 850	4.5
C172...	Double remelt	21 400	26 850	4.0

TABLE II.

Heat	Zinc, per cent	Magnesium, per cent	Titanium, per cent	Iron, per cent	Copper, per cent	Silicon, per cent	Manganese, per cent	Chromium, per cent
C169.....	5.77	0.55	0.01	0.31	0.09	0.24	0.02	0
C170.....	5.71	0.51	0.14	0.31	0.09	0.24	0.02	0
C171.....	5.68	0.47	0.14	0.31	0.09	0.24	0.02	0
C172.....	5.67	0.41	0.14	0.31	0.09	0.24	0.02	0

2. Part of this grain refining effect wore off in the remelting processes.

3. This alloy is inherently fine grained even without the addition of titanium, but titanium seems to be beneficial in promoting more uniform grain size.

4. The addition of titanium was definitely beneficial to the tensile strength and elongation of the alloy.

It must be remembered that the results in the accompanying Table I were taken from a single experiment. Physical properties in Table I are considerably lower than those which we have obtained in regular practice and are not to be considered typical of alloy O itself, since all of the alloying ingredients were not present.

Other tests are being run to check the results of Table I and to determine how much additional strength is imparted by the use of chromium. A detailed report of these investigations will be made when completed.

We are in agreement with Mr. Bonsack's contention that the alloy O limit of 0.05 per cent manganese is too low. Later specifications have raised this to 0.3 per cent manganese. We also agree that the 0.2 per cent copper limit of the alloy is not justified. Later specifications have raised this to 0.4 per cent copper. We are not, however, in agreement with the author's contention that copper as high as 1.5 per cent is desirable in aluminum-zinc-magnesium alloys.

It is generally recognized that the presence of copper in amounts above about 0.6 per cent is detrimental to the corrosion resistance of aluminum-zinc-magnesium and aluminum-zinc alloys. Investigators have found that in aluminum-zinc-magnesium alloys, those which contained 1 per cent copper were inferior in corrosion resistance to those containing 0.35 per cent copper, and that bars stressed to 75 per cent or less of their yield strength are not subject to intergranular corrosion when continually immersed in a solution of NaCl and H_2O_2, where copper was not less than 0.25 per cent and not more than 0.6 per cent. Since the excellent corrosion resistance of aluminum-zinc-magnesium alloys is one of their distinguishing features, obviously the addition of copper is not desirable in this respect.

We have made a few experiments with copper added to alloy O. While we do not have any results for the 1.5 per cent copper mentioned by Mr. Bonsack, we do have tests

for 2 per cent copper. The basic composition of the metal was as follows:

Zinc, per cent	Magnesium, per cent	Chromium, per cent	Iron, per cent	Titamium, per cent	Silicon, per cent	Manganese, per cent	Tin, per cent	Lead, per cent
5.22	0.59	0.54	0.53	0.19	0.15	0.18	0.01	0.00

The copper contents are shown along with the physical properties in the accompanying Table III.

The yield strength was increased by the addition of 2 per cent copper, but tensile strength decreased and elongation dropped considerably.

TABLE III.—PHYSICAL PROPERTIES OF ALLOY O WITH COPPER ADDED.

Heat	Copper, per cent	Yield Strength, psi.	Tensile Strength, psi.	Elongation in 2 in., per cent
O....	0.23	21 050	32 600	7.5
C41....	2.39	27 850	29 150	1.5

Other investigators have found that in aluminum-zinc-magnesium alloys the magnesium must decrease as copper increases in order to prevent loss in physical properties, particularly elongation. Where zinc and magnesium were held constant and copper increased from 0.4 per cent to 1.0 per cent, yield strength increased, but tensile and elongation decreased. When copper was still further increased to 1.75 per cent, yield strength increased still further, tensile strength fell lower, and elongation dropped to less than half its value at 0.4 per cent copper.

On the basis of such evidence we believe that the presence of 1.5 per cent copper in alloy O is undesirable.

Closure by W. Bonsack:[4]

Mr. Comstock's and Mr. Brown's discussions of my remarks concerning titanium as a minor alloying element in aluminum alloys is indeed interesting. I only wish that the rest of the material in my paper, relating to numerous other elements, were subjected to the same careful scrutiny and criticism. Only thus can progress be made.

The statement made about the effect of titanium being lost during remelting seems to require some further clarification. The second part of my paper mainly discusses aluminum-silicon alloys, as the title indicates, and the data presented deal with aluminum-silicon alloys and, therefore, the remarks should mainly be connected with these alloys. Alloy O had been singled out in this discussion as an alloy in which titanium is a very desirable element within very specific limits.

The loss of the effect of grain refining of titanium due to remelting was prompted by our own observations on large tonnages of titanium-bearing aluminum alloys. In making ingots from aluminum alloy scrap containing various amounts of titanium, we should get the benefit of the grain refining power of this element. However, in most instances, it is lost. To illustrate this statement, the accompanying Fig. 1 gives the frequency of occurrence of minor alloying elements in alloy Y. Since this diagram represents about 5 million pounds of this aluminum alloy, it should give a fair indication of the occurrence of titanium. The titanium varies from 0.01 per cent to 0.24 per cent, but only very few heats showed any grain refinement which could be attributed to a carry-over from the raw material to the ingot. In other words, it did not stand even one remelting. Furthermore, foundries operate not only on ingot

[4] Director of Laboratories, The National Smelting Co., Cleveland, Ohio.

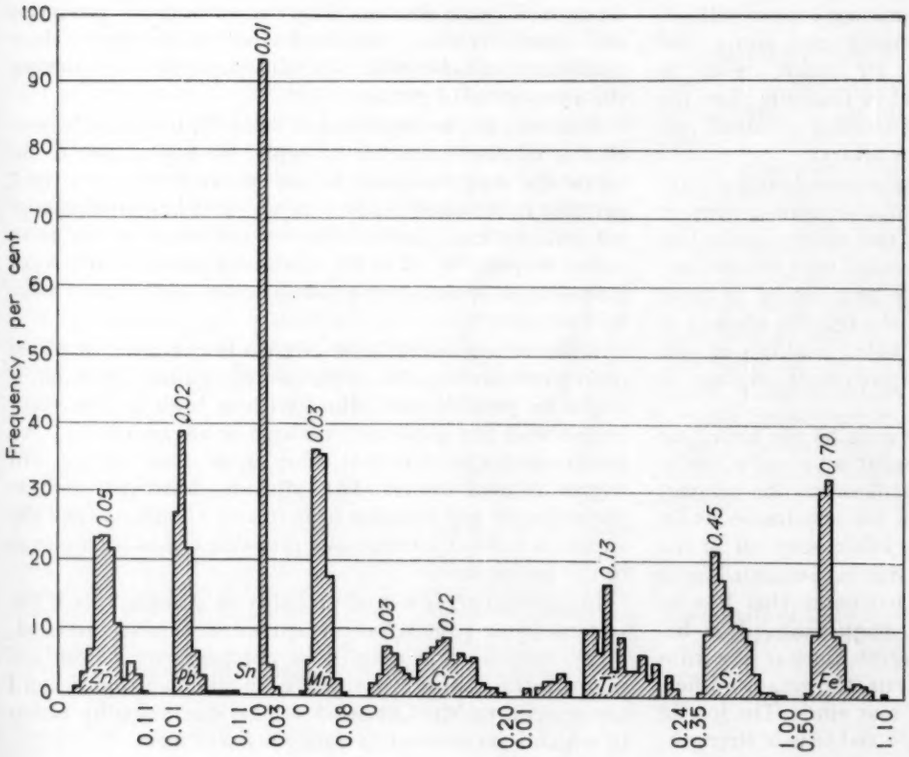


Fig. 1.—Frequency of Occurance of Minor Alloying Elements in Alloy Y. 220 Heats.

material, but they use much of their own scrap. Usually up to 50 per cent scrap goes into a charge. This scrap metal is usually remelted in large reverberatory furnaces, fluxed, and poured into ingots. These are then used with a charge of new ingots. In most of these cases, fresh titanium hardener is added in order to get uniformly fine grain. It should be stated, though, that not as much titanium has to be added as if no titanium were present at all. We have found, in many cases, when the alloy contains about 0.10 per cent residual titanium, only a small amount, such as 0.04 or 0.06 per cent needs to be added. This brings the total amount of titanium up to about 0.15 per cent, while originally only 0.10 or even 0.08 per cent of titanium was sufficient to cause grain refining.

Furthermore, not all castings can be made under ideal conditions as to melting and pouring temperature. That is to say, many castings have to be poured at a temperature of 1400 or 1500 F. which should be called an overheating of the metal. Therefore, not all foundries at all times can take the proper precautions to get the full benefit of the grain refining action of titanium.

Grain refining is still one of the mysteries which we have not solved. We know which element will refine the grain and we know the effect on the properties. We know further what amounts will do the grain refining, but we do not know what actually occurs during the process and what actually causes the grain refinement. Therefore, as stated in the paper, we must, of necessity, conjecture.

The fact that titanium forms relatively coarse needles in the aluminum alloys, particularly in silicon alloys, makes one doubt that this compound, as such, is the grain refiner. Grain refining is usually attributed to the formation of large amounts of nuclei around which the aluminum crystallizes. It is hard to imagine that the aluminum-titanium compound crystal, as it appears under the microscope, should be a nuclei for aluminum crystals.

Our observation is that aluminum-copper alloys, aluminum-magnesium alloys, aluminum-zinc alloys, and aluminum-magnesium-zinc alloys are much easier to modify or grain refine with the aid of titanium than the aluminum-silcon alloys, and the refinement obtained prevails much longer than in the latter alloys.

Alloys containing higher iron and silicon do not always show the full benefits as found in aluminum-copper or aluminum-magnesium alloys. The two examples cited by Mr. Comstock contain very low iron and very low silicon. The effects of the titanium is very pronounced in these alloys. The reason seems to lie in the relative absence of eutectic. We know that, for example, in alloys of this type, even iron additions show improvement on some of the properties.

Mr. Brown actually proved that even by the remelting of alloy O the effect of grain refinement is partially lost in spite of the fact that the analysis still shows the original amount of titanium. He states in his conclusion under No. 2, "Part of the grain refining effect wore off in the remelting processes." This loss was accompanied by a loss in properties. Mr. Brown attributes this loss of properties to the loss in zinc and magnesium. It is believed that the loss of zinc is negligible since it is within the limits of error of chemical analysis, the greatest difference being 0.04 per cent in 5.7 per cent zinc. The loss of magnesium explains the loss in yield and tensile strength, but should be accompanied by a gain in elongation, yet there exists a loss of elongation which, it might be argued, is due to loss of grain refining.

In alloys in which large amounts of euctetic are present, the titanium crystal has an opportunity to grow much larger and, therefore, the beneficial effect seems to be reduced. It is in these alloys where titanium usually segregates when it is present in large amounts.

The reduction in properties which we have reported on the 356 alloy due to the addition of titanium is not an isolated case. We find in the literature similar cases in silicon alloys.

Mr. George Sachs in "Practische Metallkunde," l. c., describes the effect of titanium on 13 per cent silicon alloy, and he states that in a modified silumin (13 per cent silicon), iron and titanium are undesirable impurities as far as the tensile properties and, possibly, the corrosion resistance are concerned. With higher iron content large brittle plates or needles are formed which decrease the elongation and make the alloy sensitive to impact. Small additions of titanium decrease these properties still more, since the amount of crystals containing iron and titanium increases rapidly. He goes on and says that silumin alloys containing copper are even more sensitive than straight aluminum-silicon alloys, since coarse iron-titanium crystals are formed at low percentages of iron. This bears out the statement made by the author and also the statement made in reference 147.

Unfortunately, most casting alloys contain relatively high iron due to the pick-up of iron in the foundry processes, especially in silicon alloys.

There is no doubt that titanium has a very beneficial effect and it is worth while in most cases to add titanium to the alloys. But the fact that the A.S.T.M. specifications limit the use of titanium in most aluminum-silicon alloys and also in some of the other alloys to 0.2 per cent seems to indicate that not only the author, but producers and consumers alike, concerned with the writing of these specifications had similar experiences and therefore limited the amount to 0.2 per cent.

Referring to the discussion of alloy O, it should be said that it was not intended to imply, by any means, to increase the copper content indiscriminately to 1 or even 2 per cent in the alloy of the type O. It is known that copper will increase corrodibility of the alloy and it is so stated on page 50. But Mr. Comstock agrees that 0.5 per cent should be acceptable, and that is much better than 0.20 per cent.

Wherever corrosion is not of great importance, or where protection can be given to the casting against corrosion, it might be possible that alloys with as high as 2 per cent copper will find good use; perhaps be advantageous. An aluminum-magnesium-zinc alloy with about 2 per cent copper is used today. This alloy is, however, used in the wrought and solution heat-treated condition, and the copper is in solid solution and probably not as corrosive as in the cast state.

In conclusion, it would probably be constructive if the statement on page 47 of my paper were made to read, "This modification often does not carry over from the ingot to the casting, particularly in silicon alloys," and I am grateful to Mr. Comstock for his discussion by means of which I am enabled to clarify my statement.

Discussion Factors Affecting Specific Gravity Values in the Proposed Method of Test for Soils[1]

Submitted by Hans F. Winterkorn:[2]

Mr. Bauer has made a concise statement and a numerical evaluation of a number of factors which must be considered in the determination of the specific gravity of soil by means of the water replacement method. Because of the theoretical and practical importance of the subject matter a few supplementary facts and ideas are offered.

1. The real purpose of determining the specific gravity of soil particles is the calculation of density utilizing the fact that density values for water of great accuracy are available in the literature. For this reason, Mr. Bauer is strongly supported in his suggestion to base the specific gravity values on water at 4 C. Thus the values are numerically identical with densities expressed in the metric system.

2. The density data, derived from the determination of specific gravities, are usually employed to calculate the porosities and voids ratios of actual soil systems, and to calculate particle sizes by means of Stokes' law in sedimentation analysis. For either purpose it is desirable to use true and accurate density data. It is an unfortunate but nevertheless a well-established fact that the water replacement method does not give true values for the specific gravity of soil particles, especially if the latter are of clay and colloidal size. Due to the compression of adsorbed water films by the action of exchangeable cations the specific gravities are found too high. As demonstrated by E. W. Russel of the Rothamsted Experiment Station[3] and by American workers,[4] the magnitude of this compression is a function of the amount and type of exchangeable cations present in a soil sample. The picture, however, is still more complicated by the fact that there exists evidence that some soil colloids may possess not only compressed but also expanded water films with specific gravities smaller than 1, this being due to a specific arrangement of the absorbed water dipoles under the influence of the crystal lattice of the soil colloids.[5] Because of these facts, soil scientists are discontinuing the use of water for specific gravity determinations, and are employing liquids which, while possessing good wetting properties, do not form either compressed or expanded absorption films. Decahydronaphthalene (decalin) and tetrahydronaphthalene (tetralin) are used extensively for this purpose. Since these liquids are easily and economically available no weighty reason can be seen why they should not also be employed instead of water in the proposed A.S.T.M. method. The error in the specific gravity value caused by the use of water is noticeable in the first decimal point.

3. Because of the great difficulty with which air adsorbed on soil particles is replaced by liquids, any standard method must give detailed instructions concerning this particular item, which are based on sufficient laboratory experience actually to fulfill the desired purpose.

[1] Edward E. Bauer, "Factors Affecting Specific Gravity Values in the Proposed Method of Test for Soils," ASTM BULLETIN, No. 125, December, 1943, p. 33.

[2] Associate Professor of Civil Engineering, Department of Civil Engineering Princeton University, Princeton, N. J.

[3] E. W. Russel, "The Interaction of Clay with Water and Organic Liquids as Measured by Specific Volume Changes and Its Relation to the Phenomena of Crumb Formation in Soils," *Philosophical Transactions*, Royal Soc. (London), Vol. 233, Series A, pp. 361–389 (1934).

[4] Hans F. Winterkorn and Robert B. B. Moorman, "A Study of Changes in Physical Properties of Putnam Soil Induced by Ionic Substitution," *Proceedings*, Highway Research Board, Vol. 21, pp. 415–434 (1941).

[5] Ralph E. Grim, "Modern Concepts of Clay Materials," *Journal of Geology*, Vol. L, pp. 225–275 (1942).

Outstanding Detroit Meeting on Corrosion

WITH A DINNER attendance of almost 400 and an additional 150 at the technical session featuring a three-paper symposium on corrosion, the meeting sponsored on December 9 by the A.S.T.M. Detroit District Committee was an outstanding success. The committee headed by C. H. Fellows, The Detroit Edison Co., has a general policy of arranging one outstanding technical meeting each year and inviting the participation of the engineering people in the area.

At the dinner in the Hotel Statler Ballroom preceding the technical session, President Dean Harvey spoke, covering some of the aims of the Society's program and he outlined some of the future planning. Past-President A. E. White, University of Michigan, was introduced and spoke briefly as did P. J. Smith, Standards Editor, who represented the Headquarters Staff.

The technical program was as follows:

Mechanism of Corrosion Processes, by Robert M. Burns, Assistant Chemical Director, Bell Telephone Laboratories, Inc., New York, N. Y.

Recent Knowledge on Corrosion Couples and Galvanic Action, by R. H. Brown, Electrochemist, Aluminum Research Laboratory, Aluminum Company of America, New Kensington, Pa.

Stress Corrosion, by E. H. Dix, Jr., Assistant Director of Research and Chief Metallurgist, Aluminum Research Laboratories, Aluminum Company of America, New Kensington, Pa.

The papers by Messrs. Burns and Brown covered in detail some of the fundamental aspects of corrosion and Mr. Dix stressed some of the practical aspects of this involved problem.

The papers by Messrs. Burns and Brown appear in this issue, see page 17. Mr. Dix will release his paper for publication later in the year.

In planning the meeting, Mr. Fellows had the close assistance of Martin Castricum, Vice-Chairman, and W. P. Putnam, Secretary. W. C. Du Comb in his usual competent fashion handled promotional aspects and the work of extending invitations to other societies and groups. E. W. Upham headed the Program Committee. Dinner arrangements were in charge of C. E. Heussner and ticket sales cleared through Mr. Putnam. All District Committee members and others aided in ticket sales and other details.

For details of 1944 Spring Meeting on Synthetic Rubbers, and Philadelphia Symposium on Plastics, see pages 5 and 9.

The Problem of Standardizing Test Methods for Mildew and Rot Resistant Treatments of Textiles[1]

By H. D. Barker,[2] G. A. Greathouse,[2] and P. B. Marsh[2]

Obviously, it is easier to speculate upon the problems involved in testing for mildew and rot resistance of fabrics than it is to develop tests that correctly evaluate various preservative treatments in terms of actual service performance. It is equally obvious, however, that an understanding of the problems involved is of fundamental importance. It is easy to devise tests—even tests that give striking contrasts with unfailing regularity under a given set of conditions or that correlate with other tests—and yet such tests may be of no practical value for predictive purposes for specified service conditions. It may also be assumed that those who are concerned with the various phases of these problems realize that the present experimental approach is, under the circumstances, abstract and may be leading us to quite erroneous conclusions.

Under normal peace-time conditions, problems of this scope and importance would be investigated more logically. We would want to investigate thoroughly the extent of the damage that is reported; to isolate and evaluate the causes, whether biological, physical, or chemical, that may be operative; and, in devising preventative treatments, we would want to study field performance month after month and season after season. The suddenness of the development of the problems with which we are concerned and the consequent need for stopgap procedures have, of course, precluded any such leisurely but logical program.

Preventive treatments and appropriate methods should take into consideration expected service conditions, types of fabrics, fungicides that are available or practical to apply, supplementary waterproofing or flameproofing materials, and other special considerations. Let us consider for a moment how certain of these may affect our operations.

While the exact service conditions may be somewhat difficult to anticipate in advance, it is assumed that specific fabrics are processed for certain articles of service. Some of these may require more protection than others. Certain articles may require little handling and thus involve less danger from the use of slightly toxic materials. Thus, sandbag fabric would require a greater degree of protection and presumably a different type of test for rot resistance than would some type of fabric that would not be expected to be in prolonged contact with the soil. With the latter we might be more concerned with "mildew" resistance than with "rot" resistance. Incidentally, there appears to be considerable confusion in regard to the use of the term "mildew" with respect to its development or prevention on fabrics. The term is frequently used to include all types of fungus and bacterial growths, tendering or rotting of the fabric by microorganisms, and even deterioration that may be caused by chemical or physical agencies. More precisely, the term "mildew" should be restricted to the development of superficial molds on fabric exposed to moist conditions. The most common of these belong to the genera *Penicillium* and *Aspergillus* and are similar to the molds that develop on cheese, oranges, and many other fruits and vegetables. The majority of these common molds that are encountered on fabric cause little or no tendering. Whether they damage the strength of the fabric, their prevention is frequently desirable and it must be admitted that it may not be easy or practicable to distinguish between such superficial molds and the development of other fungi that may or may not give a visible growth on the fabric but that result in the loss of fabric strength. In general, however, it seems preferable to distinguish the latter as rot-producing microorganisms.

In cooperative studies with the Bureau of Human Nutrition and Home Economics it has been shown that more than forty genera and species of fungi are able to secure their carbon requirements from fabric and thus bring about loss of strength. Many of these organisms differ greatly in their rate of cellulosic destruction, in their sensitivity to pH changes in substrate, their ability to use diverse materials as sources of energy, and their ability to compete with other organisms. Our laboratory results confirm those of Morris[3] and others in showing that different fungi react differently to varying dosages of different fungicides. Hence, it appears not so much a question of which fungus should be used as a test organism but rather how many fungi should be used correctly to evaluate the effectiveness of mildew and rot-resistant treatments to withstand the predominant microflora of diverse geographical regions.

Our laboratory results also agree with those of Thom, Humfeld, and Holman[4] in emphasizing the futility of attempting evaluation by the use of mixed cultures. Certain of these details will be brought out in the discussion of pure culture techniques that follows. In general, it may be stated that the mildew types of

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 260 S. Broad St., Philadelphia 2, Pa.

[1] Presented at the Symposium on Mildew Resistance at the October, 1943 meeting of the Society's Committee D-13 on Textile Materials in New York, N. Y. This paper together with the other papers presented at this meeting will be issued as a separate publication.

[2] Division of Cotton and Other Fiber Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture, Washington, D. C.

[3] L. E. Morris, "Mildew in Cotton Goods, Antiseptics, and the Gro vth of Mold Fungi on Sizing and Finishing Materials," *Journal* Textile Inst., Vol. 18, pp. T99–T127 (1927).

[4] C. Thom, H. Humfeld, and H. P. Holman, "Laboratory Tests for Mildew Resistance of Outdoor Cotton Fabrics," *American Dyestuff Reporter*, Vol. 23, pp. 581–586 (1934).

growth, such as *Penicillium* and *Aspergillus*, are more tolerant to many fungicides than are the rot-producing fungi, such as *Chaetomium* and *Metarrhizium*.

The importance of considering expected service conditions in devising treatments and appropriate test procedures may be illustrated by considering the interrelationship of the various factors that may be involved in fabric deterioration.

Biological deterioration, our primary concern, results from microorganisms utilizing the fabric as a source of carbon. This is accomplished by means of producing cellulase or other enzymes. Maximum deterioration results when the fungus finds favorable environmental conditions. These include the right kind and proper balance of nutritive materials, suitable temperature and moisture conditions, freedom from competition or inhibition resulting from deleterious by-products of other microorganisms. Moreover, fungicidal treatments, test organisms, and the kind of fabric, all influence each other. Thus, the microorganisms may affect the fabric or the preventative compounds. Likewise the type of mildew or rot preventive used may affect the microorganism, and indirectly affect the fabric, or the preventive treatment may directly affect the fabric.

When soil contact tests are applied they enormously increase the complexity of the problem. The amount of organic matter and other nutrients cannot be accurately controlled. Likewise, the kind and amount of inoculum or cellulose-destroying microorganisms are uncontrolled. The difficulty of determining and maintaining optimum and comparable moisture content of different soils is an almost insurmountable difficulty. Variation in ionic adsorption and other colloidal phenomena are to be expected. Organic acids or metabolic by-products of microorganisms in the soil may bring about an undetermined modification of the preservative treatment or affect the fabric or the biological activity. Indeed there are so many unknown and uncontrollable factors that it may be questioned whether we shall ever have a standardized and reproducible soil burial test. Despite these many objections, however, some soil contact test procedure is unquestionably one of the logical tests for fabrics that are expected to be in contact with soils. It may well be argued that, since it is usually not known in advance what soils, sandbag and similar fabrics may come in contact with, we should subject such fabric not to one soil burial test but to several different types of soils—possibly under varying temperatures and moisture conditions.

We have demonstrated that different soils do behave differently in rate of deterioration or even in the order of classifying relative superiority of various treatments and, with the same soil, temperature and moisture changes give results that do not agree.

In commercial practice mildew and rot preventives are naturally applied to fabrics at higher concentrations than are necessary to prevent the growth of microorganisms. This, of course, is to provide for the gradual loss of the protective agent by leaching, photochemical action, adsorption, or other weathering agencies operative during the life of the fabric. Thus, in devising practical test procedures there arises the need for two distinct types of tests—evaluation tests and acceptance tests.

Evaluation tests should determine:

1. Whether the proposed protective agent has fungicidal or fungistatic properties.
2. The degree of resistance the proposed protective agent has to leaching, photochemical action, ionic adsorption, and other weathering agencies that eventually reduce the concentration on the fabric to a value that will permit growth of deleterious microorganisms.
3. The amount of the protective agent that must be applied to the fabric to assure practical service life.

In evaluation tests much detailed investigation is frequently required and test procedures should therefore be sufficiently sensitive to detect losses by leaching, or photochemical action, and the test should of course be reproducible and reliable so that the comparative value of fungicides may be determined.

Acceptance tests, on the other hand, should be rapid and of a routine nature, and be capable of detecting spotty application or ascertaining that the kind and amount of desired preventive treatments have been applied. They should be sufficiently severe properly to rank commercial treatments that contain excesses of the treating agent.

One possibility that we feel has not been sufficiently explored is the substitution of chemical for biological tests as acceptance procedures where simple quantitative chemical tests are applicable.

Much discussion has arisen and will undoubtedly continue to arise regarding the relative merits of pure culture procedures as compared with each other or as distinguished from various types of soil contact tests.

It is hoped that this symposium will do much to clear up some of this confusion and establish the fact that several of the tests have an important place in evaluating mildew and rot-preventative treatments. Possibly much may also be done in considering tests that, with suitable modifications and standardization, may serve as acceptance tests.

It is our opinion, however, that these several tests should be well understood with respect to their objectives, relative advantages and disadvantages, and that each must be used with discrimination and correctly interpreted.

Despite all the shortcomings of the soil burial procedure or other soil contact tests, we feel that soil contact tests have an appropriate place in testing treated fabrics that are expected to be exposed to soil contacts. On the basis of data that have come to our attention, we feel that it would be very dangerous to use any soil contact test as the only test procedure for evaluating or for accepting treated fabrics that are not expected to be in prolonged contact with the soil. It seems obvious that there are so many factors operative in the soil that may not be operative to any considerable degree in above-ground exposures and *vice versa* that the test procedure should be judicially chosen and carefully interpreted.

While acceptance test procedures and evaluation test procedures may for practical purposes be considered distinct types of tests, it should be borne in mind that this does not preclude the possibility that they may differ from each other only in methods of application or in subjecting

the fabric to suitable modifying procedures. It is clear that acceptance test procedures are by far the more difficult in that some accelerated procedure must be employed for removing or inactivating the excess toxic material. With some knowledge of the nature of the preservative compounds it is of course not difficult to devise artificial procedures for removing or inactivating the excess toxic material on freshly treated fabrics. It is, however, a difficult problem to remove this excess so as to simulate or predict natural degradation of the treated fabric.

In conclusion, it is felt that while our ignorance is unfortunately profound with respect to mildew- and rot-resistance problems and appropriate test methods for treated fabric, this symposium provides opportunity for diverse agencies to piece together what information is available so that we may, individually and collectively, do a better job.

Committee B-6 on Die-Cast Metals and Alloys Continues Work

Successful in Raising Funds for Research

PRACTICALLY ALL A.S.T.M. standing technical committees have profoundly influenced technical developments in their respective engineering materials fields. Through the promulgation of widely recognized standard specifications, used for purchasing, and the standardized test methods for evaluating the properties of materials, the committees' deliberations and recommendations have acted as stabilizing elements in many fields. And simultaneously with the standards work intensive research activities being carried out, have led to the development of new products and improvements.

No standing committee has influenced its field more than Committee B-6 on Die-Cast Metals and Alloys, and a recent statement that "There is little doubt that much of the phenomenal progress which the die casting industry has made in recent years is due to the confidence which consumers have in the work done by this committee," is justified. This committee was organized in 1930 as a separate standing group to continue activities previously carried on through a subcommittee of another group. Almost immediately the committee planned and began an extensive research program, much of it outdoor exposure tests, to supply dependable information on the properties of

Officers of Committee B-6 on Die-Cast Metals and Alloys

CHAIRMAN: J. R. Townsend, Materials Standards Engineer, Bell Telephone Laboratories, Inc.

VICE-CHAIRMAN: J. C. Fox, Chief Metallurgist, Doehler Die Casting Co.

SECRETARY: G. L. Werley, The New Jersey Zinc Co.

CHAIRMAN OF SUBCOMMITTEES:

I on Aluminum-Base Die-Casting Alloys—E. E. Thum, Editor, *Metal Progress*.

II on Zinc-Base Die-Casting Alloys—A. E. Weiss, Factory Manager, The Superior Die Casting Co.

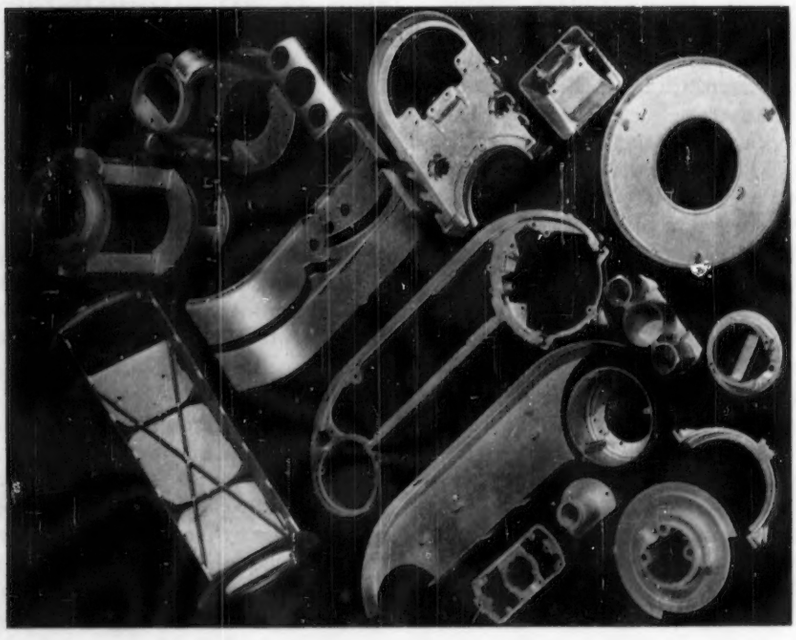
III on Tin- and Lead-Base Die-Casting Alloys—G. O. Hiers, Chemist, National Lead Co., Research Laboratories

IV on Physical Tests of Die Castings—R. L. Templin, Assistant Director of Research and Chief Engineer of Tests, Aluminum Company of America

V on Exposure and Corrosion Tests—W. M. Peirce, Chief, Research Division, The New Jersey Zinc Co.

VII on Magnesium-Base Die-CastingAlloys—J. A. Gann, Chief Metallurgist, The Dow Chemical Co.

VIII on Brass Die-Casting Alloys—J. C. Fox, Chief Metallurgist, Doehler Die Casting Co.

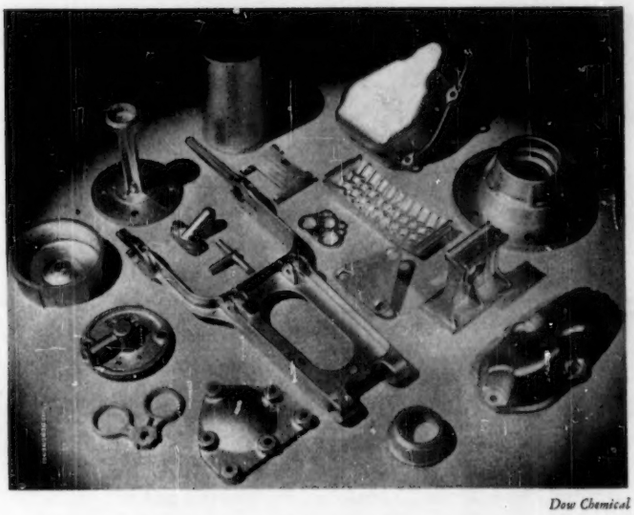


Aluminum Company of America

Aluminum alloy die castings in a widely used dental unit. Holes, flanges, lugs, collars, thin sections and stiffeners are die cast right into the aluminum parts so that a minimum of machinery is necessary before assembly. Lightness, strength, close and permanent dimensions are other important features in this use.

New Jersey Zinc Co.

Another illustration of how die castings are aiding in the war effort. These zinc-alloy shock absorber parts are used on jeeps.



Dow Chemical

Parts of various sizes and shapes are made from magnesium die-casting alloys.

alloys suitable for die casting. Details of references, n oteson a number of technical papers developed by the committee as its work progressed, and such data are included in the December BULLETIN, page 47, in the Research Article. There was also noted an extensive new program of work on certain compositions which will include tension tests and accelerated and normal aging tests.

Partly to liquidate a small outstanding debt, and particularly to provide for future outlays for committee work, principally for the construction of exposure racks, the preparation and handling of specimens, etc., the financial subcommittee under the chairmanship of G. O. Hiers has recently completed raising necessary funds. Mr. Hiers' final report, made to J. R. Townsend, Chairman of Committee B-6, shows the success of the subcommittee's efforts in the solicitation of funds from various producers, manufacturers, consumers and general interest groups.

The American Die Castings Institute, selected as being representative of the "Manufacturers" of die castings, was invited to contribute and very generously did so in the amount of $1000. The balance of the contributions received, totaling $1800, consisted of amounts ranging from $25 to $150 from twenty-six organizations holding membership on Committee B-6.

The total receipts, therefore, amounted to $2800, *or 40 per cent in excess of the goal set.*

This splendid response is another continuing indication of the appreciation that it is felt industry has toward the committee's work.

The following list comprises the twenty-seven contributors who have generously responded to the invitation to contribute:

Aluminum Company of America
Aluminum and Magnesium, Inc.
American Brass Co.
American Die Casting Institute
American Machine and Metals
American Smelting and Refining Co.
American Society for Metals
Apex Smelting Co.
Automatic Electric Co.
Bell Telephone Laboratories, Inc.
Briggs & Stratton Corp.
Chrysler Corp.
Dow Chemical Co.
Duquesne Smelting Co.
General Electric Co.
Gerity-Adrian Manufacturing Corp.
International Harvester Co.
H. Kramer and Co.
National Cash Register Co.
National Lead Co.
National Smelting Co.
New Jersey Zinc Co.
St. Joseph Lead Co.
Sperry Gyroscope Co.
Titan Metal Manufacturing Co.
U. S. Smelting, Refining & Mining Co.
Westinghouse Air Brake Co.

Specifications for Die Castings:

Aluminum-Base Alloys in Ingot Form for Die Castings	B 125-42 T
Aluminum-Base Alloy Die Castings	B 85-42
Copper-Base (Brass) Alloy Die Castings	B 176-42 T
Lead and Tin-Base Alloy Die Castings	B 102-39 T
Magnesium-Base Alloys in Ingot Form for Sand Castings and Die Castings	B 93-41 T
Magnesium-Base Alloy Die Castings	B 94-40 T
Zinc-Base Alloy Die Castings	B 86-43
Zinc-Base Alloy Die Castings, Special Grade	B 186-42 T

Turn page for other illustrations of die-castings.

Call for Annual Meeting Papers

AT ITS meeting scheduled for A.S.T.M. Headquarters on February 21, Committee E-6 on Papers and Publications which is responsible for the development of the technical program for the 1944 Annual Meeting will consider the various offers of papers. Previous announcements have been made to the members through the BULLETIN and elsewhere of the desire to develop the program at the earliest possible date and Committee E-6 will appreciate having offers as far in advance of the meeting as possible. Forms on which to submit offers can be obtained from A.S.T.M. Headquarters.

Fiftieth Birthday of Heating and Ventilating Engineers

THE AMERICAN Society of Heating and Ventilating Engineers will commemorate its Fiftieth Anniversary at the Annual Meeting in New York City, January 31 to February 2, inclusive. 1944 also marks the Twenty-fifth Anniversary of the Society's Research Laboratory. A.S.T.M. Vice-President J. R. Townsend, Bell Telephone Laboratories, Inc., is the official representative of A.S.T.M. at the A.S.H.V.E. Annual Meeting. Among the interesting features of the meeting are a reception and Oldtimer's Reunion, and on February 2, the Annual Banquet at which Lt. Comdr. F. C. Houghten, USNR, who has been active in various phases of A.S.T.M. work, will receive the F. Paul Anderson Medal.

New Jersey Zinc Co.

The bouchons for hand grenades are die cast from zinc alloys.

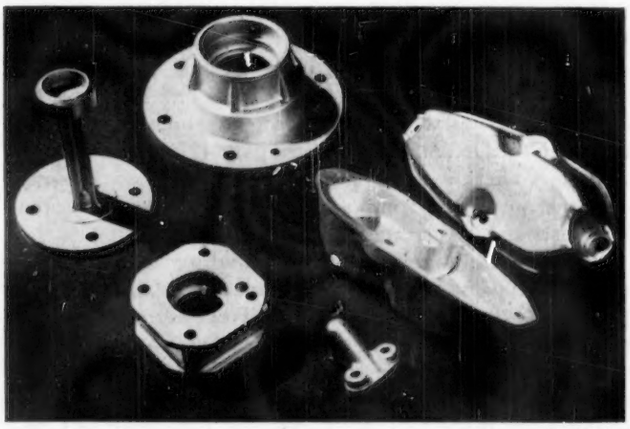
More Data on Wire Tests

Because of the interest in corrosion resistance of lead-coated wires, and their significant relation to certain of the wire test research under way, there have been added to the 1943 Annual Report of Committee A-5 on Corrosion of Iron and Steel data on chemical analysis of coatings of lead-coated wires as determined by the National Bureau of Standards. This Committee is in charge of country-wide field tests of wire products. These data were developed too late to be included in the preprint of the report, but will be found in the 1943 *Proceedings* as part of the very important wire inspection report. This report gives voluminous data, with pertinent discussion on wire and wire products specimens which have been on exposure throughout the U. S. in various atmospheres for about six years. Full details of the tests have been published previously. (Published references were given on page 6 of the December, 1943, Bulletin in the Research Article).

The following is a report on recently completed chemical analyses made by the National Bureau of Standards of the coatings on wire samples taken from the same lots as the lead-coated wire undergoing exposure tests. These analyses were not made when the "referee" tests[1] were carried out at the Bureau (mostly in 1937 and 1938), but the wire which would have been used for analysis was saved.

The analyses reported below refer to the specimens shown in micrographs in Table I-0 of the 1939 Report of Committee A-5.[2] Examinations were made for tin and zinc contents which seem more significant in the characterization of lead coatings than analyses for cadmium, copper, and iron which were made in 1937 and 1938 to characterize the zinc coatings.

The coating weight determinations recently made do not check very well with those made at the time of the referee tests as shown in the following table:



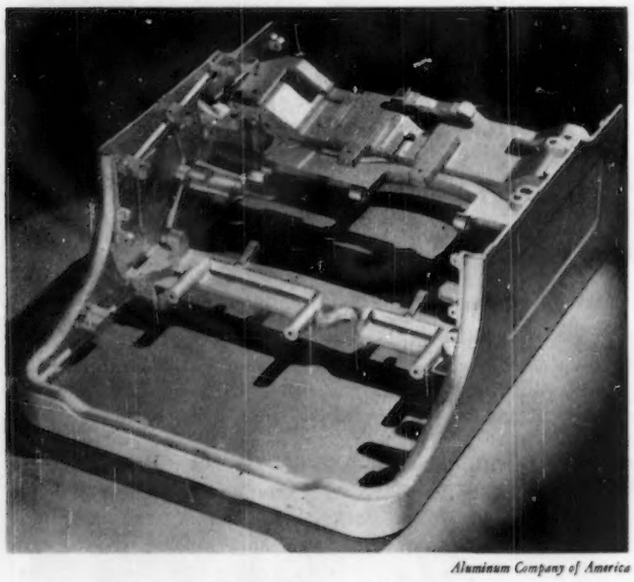
Dow Chemical

Another example of parts where magnesium die castings are used.

	Wire Lot Number			
	B-040	B-041	B-042	B-043
Average diameter of wire, in.	0.188	0.144	0.117	0.08
Weight of coating, oz. per sq. ft.	1.60	1.10	1.73	1.12
	1.40[a]	1.48[a]	1.68[a]	1.90[a]
Tin content, oz. per sq. ft.	0.004	0.002	0.003	0.005
Zinc content, oz. per sq. ft.	0.19	0.14	0.21	0.25

[a] Previously published coating weight determinations.

Reference to the micrographs in the 1939 Report[2] indicate that these lead-coated wires have a thin layer adjacent to the steel, differing in appearance from overlying lead. From these micrographs and the results of the analyses shown above it is reasonable to deduce that this underlying or bonding layer is zinc. Committee A-5 does not have under test at present any lead-coated wires which do not show this bonding layer. The committee does not wish to deduce or conclude that the performance of the specimens now on test is better, worse, or equivalent to specimens so fabricated that they are devoid of this bonding layer.



Aluminum Company of America

A noiseless typewriter frame of die-cast aluminum.

[1] Report on Original Characteristics of Wire and Wire Products Involved in Field Exposure Tests, *Proceedings*, Am. Soc. Testing Mats., Vol. 39, p. 101 (1939).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 39, p. 144 (1939).

Two New Standing Committees on Adhesives and on Metal Powders and Metal Powder Products

FORMAL ORGANIZATION is expected shortly to be announced of two new A.S.T.M. standing committees, one on Adhesives, the other on Metal Powders and Metal Powder Products. For some time the Executive Committee has been giving consideration to work in these fields, in fact for adhesives over quite an extensive period. The desirability of organized work on standardization involving probably the development of necessary information on properties and tests has been stressed to an increasing extent in recent months, and has led to the formation of the new groups.

Adhesives:

There has been little published in A.S.T.M. volumes relating to the subject of adhesives aside from an extensive "round-table" discussion 20 years ago and a recent paper dealing with starch adhesives. Under way currently in Committee D-20 on Plastics are studies and discussion on certain adhesives for which standards are very urgently needed. This work will be correlated with the new Adhesives Committee when the latter gets organized. It is contemplated that the committee will cover adhesives derived from animal, mineral, or vegetable sources, and also synthetic products. Leading authorities in the field, representing producers and consumers are being asked to serve.

T. R. Truax, who has been concerned with A.S.T.M. work for many years, and who is Principal Wood Technologist, U. S. Forest Products Labs., Madison, Wis., has accepted appointment as Temporary Chairman of the Committee. One need only review the list of those who exhibited interest in the development of the committee to see what widespread applications there are for adhesives, and to realize that the committee has a tremendous field of activity confronting it. However, with the close cooperation which the chairman of any A.S.T.M. committee can confidently anticipate from his members, Mr. Truax and his committee will shortly evaluate the immediate problems which need solution and proceed.

Metal Powders and Metal Powder Products:

One of the situations bringing the organization of the new committee on Metal Powders and Metal Powder Products to the fore was the symposium held in Buffalo at the 1943 March Spring Meeting. Subsequent discussions with leaders in this field indicated that the Society could render important service to both producers and users of metal powders and compacts by establishing a technical group to consider standardization problems. There has been a splendid response to invitations to participate in the work. The Temporary Chairman is W. A. Reich, Works Laboratory, General Electric Co., Schenectady, N. Y., and W. R. Toeplitz, Bound Brook Oil-Less Bearing Co., Bound Brook, N. J., is Temporary Secretary. Personnel of this committee will be announced shortly and other details given.

Study Committee to View Society Objectively

AS A RESULT of suggestions emanating from a meeting of the Society's officers late in 1943, the Executive Committee at its October meeting authorized the appointment by the President of a special Study Committee to review and consider objectively various aspects of the Society's work, in particular future trends of development. It was planned that the committee should consist of 10 to 12 individuals representing various viewpoints and experiences, and the group would be free to draw upon A.S.T.M. technical committees and the general membership for ideas and information.

Such a committee has been appointed and acceptances received from all of the members. H. S. Vassar, Public Service Electric and Gas Co., the Chairman, is a Past-President of the Society and present Chairman of Committee E-10 on Standards. He has been active in a number of Society technical and administrative matters, and each of the members of the Study Committee also has been concerned with various phases of the Society's work and with technical problems in the materials field. Some of them have been or are members of the Executive Committee. The personnel follows:

H. S. Vassar (chairman), Public Service Electric and Gas Co., Maplewood, N. J.
A. G. Ashcroft, Alexander Smith & Sons Carpet Co., Yonkers, N. Y.
P. H. Bates, National Bureau of Standards, Washington, D. C.
A. W. Carpenter, B. F. Goodrich Co., Akron, Ohio
T. G. Delbridge, Atlantic Refining Co., Philadelphia, Pa.
T. A. Fitch, Los Angeles Bureau of Standards, Los Angeles, Cal.
J. H. Foote, Commonwealth and Southern Corp., Jackson, Mich.
J. R. Freeman, Jr., American Brass Co., Waterbury, Conn.
F. E. Richart, University of Illinois, Urbana, Ill.
J. R. Townsend, Bell Telephone Laboratories, Inc., New York, N. Y.
E. W. Upham, Chrysler Corp., Detroit, Mich.

The exact scope of the committee's studies has not been delineated, although there are numerous problems to be considered, many arising from the rapid growth in A.S.T.M. activities. Some items may doubtless be referred to other committees for detailed report including the publication setup, the Society's procedure for acting on standards, location and time of national meetings, and other problems.

Society Officers to Visit West Coast

THE PRESIDENT, Dean Harvey, and Secretary-Treasurer C. L. Warwick are planning to visit the Pacific coast in March and attend meetings sponsored by the two District Committees in Northern and Southern California. On March 15 there is to be a dinner meeting in San Francisco while the meeting in Los Angeles is scheduled for March 20. At each of these meetings the President and Secretary-Treasurer will speak, and during their stay will have meetings with the District Committee members and meet other members of the Society. Detailed notices of the meeting are being sent to all A.S.T.M. members and committee members in the respective district areas.

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PHILADELPHIA, PENNA.

1943 Proceedings Being Completed

PRESS WORK ON the voluminous 1943 *Proceedings* is now under way so that distribution of the book to members may be made soon after publication of this BULLETIN. There have been the expected delays occasioned by printing problems, manpower shortage at the printer and binder's and a few other complications, but these delays will not detract from the technical value of this volume which annually is considered such an improtant addition to the literature in the field of engineering materials. The book, carrying as it does so many committee reports and extensive technical papers on a wide variety of problems is one of the distinct assets of membership in A.S.T.M., and each member, of course, receives a copy, with extra copies available at $6 each (the list price is $9).

Notes on the Proceedings:

Outstanding components of the 1943 volume include the Edgar Marburg Lecture on "Wood as an Engineering Material" by L. J. Markwardt; the Symposium on the Identification of Water-Formed Deposits; Symposium on Hardness Testing; and other groups of reports and papers. While much of the material was preprinted and distributed to the members in advance of the annual meeting there were many items that could not be distributed and consequently they will be received by the members for the first time in this book. Examples in this category include the Hardness Symposium with its four papers and interesting discussion; the very extensive paper dealing with "Tests of the Fire Resistance and Thermal Properties of Solid Concrete Slabs and Their Significance," by C. A. Menzel; "Interpretation of Creep-Test Data," by P. G. McVetty; "Studies to Develop an Accelerated Test Procedure for the Detection of Adversely Reactive Cement-Aggregate Combinations," by T. E. Stanton; "Variations in Strength of Portland Cements Conforming to the Same Specifications and the Relations of Such Variations to Concrete Control," by S. P. Wing and Arthur Ruettgers.

Those concerned with the properties of metals at elevated temperatures will be much interested in several fundamental papers in this field. The section on cement and concrete is this year noteworthy because of the excellent contributions from outstanding authorities. There are two interesting papers on determination of dissolved oxygen in feedwaters including laboratory and field methods. Several papers deal with plastics.

About 400 pages of the 1350-page volume are devoted to committee reports with several special discussions relating to some of the committee work. The balance of the 1350-page volume comprises the technical papers and discussions.

1943 Supplement to Book of Standards Issued

THE THREE SUPPLEMENTS to the respective Parts of the 1942 Book of A.S.T.M. Standards are nearing completion and mailing will start soon. These volumes, comprising the first supplement to the current Book of Standards, are in the usual three parts—I, Metals; II, Nonmetallic Materials—Constructional; and III, Nonmetallic Materials—General. Under the Society's publication scheme, these Supplements are an essential part of the Book of Standards, bringing it up to date. While there may be some change in the plans, necessitated by the very heavy distribution of the books, the normal procedure would call for another Supplement late in 1944.

The following statistics pertaining to the 1943 Supplements may be of interest:

STATISTICS ON 1943 SUPPLEMENTS.

Part	New Standards	Revised Standards	New Tentative Standards	Revised Tentative Standards	Total	Total Pages
I	14	12	15	20	61	305
II	17	2	16	8	43	152
III	20	7	50	20	97	516

Enclosed with each Part of the Supplement are yellow gummed stickers which should be attached to the indicated pages in the Book of Standards, thus calling attention to any obsolete items. Where tentative revisions have been issued, these are noted on the stickers also.

Emergency Standards and Provisions:

Each Supplement Part includes emergency standards issued since the printing of the 1942 Book of Standards, and also included with each Part are the emergency alternate provisions ("pink slips") effective with the book.

Society Membership at Peak

IN HIS REPORT to the Executive Committee covering membership for 1943, the Secretary-Treasurer included a number of interesting statistics indicating that the membership was at an all-time high, that the number of new members elected during the year was by far the largest, and that the net gain of 333, which figure is obtained by deducting deaths, resignations and those dropped, from the total of new members, was also in excess of any previous year. As of December 31 there were 5026 members in A.S.T.M., the largest portion, of course, being individual members, including libraries, government departments, etc., totaling almost 3500, with company, group, and association members numbering 1236, 166 Sustaining Members and just under 150 junior members. There were almost 300 student members not included in the above figures. Largest percentage net growth during the

year was in the junior class, with "company" membership next.

The banner year in membership is a result of various factors, notably the tremendously accelerated production throughout industry, but is also a result of extension of A.S.T.M. work into new fields and a more widespread appreciation of the A.S.T.M. and its functions. The distribution of the Society's publications has been very notable during the year as the report of the Finance Committee shows and this has a bearing on new members. (Details on finances will be covered in the March ASTM BULLETIN.) There has been continuing support by the members in procuring new organizations and individuals to benefit from affiliation with the Society.

Sustaining Membership:

Recently distributed to the representatives of all company members of the Society was a brochure on Sustaining Membership outlining some of the advantages of this class of membership and also including an interesting chronology itemizing some of the important developments throughout the Society's 40-year existence. This class of membership was instituted in 1930 to provide an opportunity for companies and such organizations, which inherently benefit more from the industrial work of the Society than do individuals, to support the activities to a degree more commensurate with its advantages, through payment of annual dues of $100. The growth, in recent years, particularly, of number of sustaining members, has been exceedingly gratifying and it is hoped that a number of additional companies will transfer to this class.

A complete list of the 166 companies in this class as of August 16, 1943, appears in the 1943 A.S.T.M. Year Book.

The following organizations became Sustaining Members during 1943:

Baker and Co., Inc.
Barber-Greene Co.
Calumet Refining Co.
Crane Co.
Gulf Research and Development Corp.
Johns-Manville Corp.
Lever Brothers Co.
Liquid Cooled Engine Div., The Aviation Corp.
Lone Star Cement Corp.
Lunkenheimer Co., The
Matam Corp.
Meyer Engineering Co.
Mica Insulator Co.
National Lead Co.
National Malleable and Steel Castings Co.
Peoples Gas Light and Coke Co.
Phelps Dodge Refining Corp.
Western Union Telegraph Co., The

The latest organizations to become Sustaining Members in January, 1944, include the following:

American Bosch Corp.
Bridgeport Brass Co.
Casein Co. of America, Div. of Borden Co.
Central Scientific Co.
Consolidated Mining and Smelting Co. of Canada, Ltd.
Continental-Diamond Fibre Co.
Greiner Co., The Emil
Merry Brothers Brick and Tile Co.
Pittsburgh Plate Glass Co.
Precision Scientific Co.

Any members of the Society who would like to have a copy of the brochure on Sustaining Membership which includes the "A.S.T.M. Chronology" can obtain one on request from A.S.T.M. Headquarters.

Schedule of A.S.T.M. Meetings

DATE	COMMITTEE	PLACE
February 21	E-6 on Papers and Publications	A. S. T. M. Headquarters,
February 21	B-4 on Electrical-Heating, Electrical-Resistance and Electric-Furnace Alloys	Engineering Societies Building New York, N. Y.
February 21, 22	D-9 on Electrical Insulating Materials	Benjamin Franklin Hotel Philadelphia, Pa.
February 22	B-9 Metal Powder and Metal Powder Products (Organization Meeting)	Waldorf-Astoria, New York, N. Y.
February 22, 23	Philadelphia District (Symposium on Plastics)	Franklin Institute and Benjamin Franklin Hotel
February 23, 24	D-20 on Plastics	Benjamin Franklin Hotel Philadelphia, Pa.
February 28–March 3	SPRING MEETING AND COMMITTEE WEEK	Netherland Plaza Cincinnati, Ohio
March 3, 4	C-1 on Cement	Hotel Traylor Allentown, Pa.
March 8–10	D-13 on Textile Materials	Park Central Hotel New York, N. Y.
March 13, 14	D-12 on Soaps and Other Detergents	Hotel New Yorker
March 15	Northern California District	San Francisco
March 20	Southern California District	Los Angeles, Calif.
March 28	C-9 on Concrete and Concrete Aggregates	Pittsburgh, Pa.

Society to Publish War Report on Spectrographic Standards

CONSIDERATION of a request from the War Metallurgy Committee to publish a Report on Standards for Spectrographic Analysis of Metals and Alloys by Dr. W. R. Brode, Ohio State University, resulted in a decision after consultation with A.S.T.M. committee officers concerned to proceed with this project. The suggestion that this important study be undertaken emanated from A.S.T.M. Committee E-2 on Spectrographic Analysis, and the War Metallurgy Committee which is advisory both to the Office of Scientific Research and Development and to WPB, engaged Dr. Brode to make the extensive survey necessary, and prepare the report. The survey report involves spectrographic standards and present methods of spectrographic analysis of metals and alloys and includes suggestions on projects which might be subsidized so as to improve the operation and efficiency of metallurgical production through improved methods of analysis and control.

Five A.S.T.M. members acted as an advisory committee including Messrs. J. D. Sullivan, H. V. Churchill, T. A. Wright, B. F. Scribner, and O. S. Duffendack. Acting on an affirmative recommendation from the Committee E-2 officers, the Society will proceed with editing of the report. It is hoped publication can be effected within the next few months. This report should be of widespread interest and service because of the growing importance of this field and the need for adequate information on standards.

Actions on Standards Continue; Brass and Bronze Castings, Die-Castings, Mica, Rubber Products, Plastics

NUMEROUS RECOMMENDATIONS from several standing technical committees affecting important specifications and tests have been approved by the Society's Committee E-10 on Standards since publication of the December, 1943, BULLETIN, at which time announcement was made of another group of approved actions. The materials covered by the latest recommendations include copper alloy castings, die castings, electrical insulating materials, rubber products, and plastics.

Among the interesting recommendations are new test methods for evaluating various properties of rubber-coated fabrics, now so widely used in many products relating to the war endeavor; also four new tentative methods of test for determining various properties of plastics, their resistance to accelerated service conditions; flammability (self-extinguishing type); impact, tensile, and compressive strengths at subnormal and supernormal temperatures.

A list of the actions approved, with dates when the items became effective, is given on this page.

Optional Test Bars in Casting Specifications:

Problems involved in the preparation of test specimens for evaluating castings of different copper alloys led Committee B-5 on Copper and Copper Alloys, Cast and Wrought through its Subcommittee X to develop data and a report on "Machined *versus* As-Cast Test Specimens for Copper Alloy Sand Castings." This material, published as part of the 1942 annual report of Committee B-5, 1942 *Proceedings*, page 199, was prepared by Messrs. J. J. Curran, J. W. Bolton, F. L. Wolf, and W. E. Martin. Those participating in the work concluded that certain types of specimens in A.S.T.M. standards could be improved, and that some other types might be employed. This study led to discussion in the committee and eventual approval of the new action which as the accompanying list shows calls for emergency alternate provisions in eight brass and bronze casting standards giving the option of casting coupons in accordance with certain dimensions and practices prescribed and in some cases giving the manufacturer the option of testing without machining the gage length. (See back portion of this BULLETIN for details.)

Zinc-Base Alloy Die Castings:

Emergency alternate provisions have been in effect for some time involving the Tentative Specifications for Zinc-Base Alloy Die Castings (EA – B 86a). Because of the improved aluminum situation it is recommended that two emergency alloys, XXIV, and XXVI, now be dropped, since these alternate compositions had provided for lower aluminum content. With these changes, the only emergency provision now affecting Specifications B 86, which have three compositions, is the one permitting 0.25 max. per cent copper in alloy No. XXIII, the regular requirement in this instance being 0.10 max. copper.

A number of the Emergency Alternate Provisions recently approved are published in this BULLETIN. They also are being furnished as "pink slips" with the respective parts of the 1943 Supplement to the Book of Standards, distribution of which is to start soon.

Specifications for Rubber Products:

In addition to the new Tentative Methods of Testing Rubber-Coated Fabrics (D 751 – 43 T), A.S.T.M. Committee D-11 on Rubber Products has acted to have its four emergency specifications covering various types of compounds for insulated wire and cable issued as regular tentative standards. From the accompanying box it will be

Recent Actions by Committee E-10 on Standards

NEW AND REVISED TENTATIVE STANDARDS

Specifications for:

- Chloroprene Sheath Compound for Electrical Insulated Cords and Cables (D 752 – 43 T).[1]
- Chloroprene Sheath Compound for Electrical Insulated Cords and Cables Where Extreme Abrasion Resistance Is Not Required (D 753 – 43 T).[1]
- Insulated Wire and Cable: Heat-Resisting Synthetic Rubber Compound (D 754 – 43 T).[1]
- Insulated Wire and Cable: Performance Synthetic Rubber Compound (D 755 – 43 T).[1]
- Natural Block Mica and Films Suitable for Use in Fixed Mica-Dielectric Capacitors (D 748 – 43 T) (new).
- Vinylidene Chloride Molding Compounds (D 729 – 44 T).
- Polystyrene Molding Compounds (D 703 – 44 T).

Methods of:

- Testing Rubber-Coated Fabrics (D 751 – 43 T) (new).
- Test for Compressive Strength of Plastics (D 695 – 44 T).
- Test for Resistance of Plastics to Accelerated Service Conditions (D 756 – 44 T) (new).
- Test for Flammability of Plastics, Self-Extinguishing Type (D 757 – 44 T) (new).
- Impact Strength of Plastics at Subnormal and Supernormal Temperatures (D 758 – 44 T) (new).
- Test for Tensile Strength and Compressive Strength of Plastics at Subnormal and Supernormal Temperatures (D 759 – 44 T) (new).

EMERGENCY ALTERNATE PROVISIONS

Tentative Specifications for:

- Bronze Castings for Turntables and Movable Bridges and for Bearing and Expansion Plates of Fixed Bridges (B 22 – 42 T).
- Tin-Bronze and Leaded Tin-Bronze Sand Castings (B 143 – 42 T).
- High-Leaded Tin-Bronze Sand Castings (B 144 – 42 T).
- Leaded Red Brass and Leaded Semi-Red Brass Sand Castings (B 145 – 42 T).
- Leaded Yellow Brass Sand Castings for General Purposes (B 146 – 42 T).
- Zinc-Base Alloy Die Castings (B 86 – 43).

Standard Specifications for:

- Castings of the Alloy: Copper 88 per cent, Tin 8 per cent, Zinc 4 per cent (B 60 – 41).
- Steam or Valve Bronze Castings (B 61 – 42).
- Composition Brass or Ounce Metal Castings (B 62 – 41).

[1] These four specifications, D 752 through D 755, were formerly Emergency Specifications ES – 28, ES – 30, ES – 33, and ES – 34, respectively.

seen that these emergency standards covered chloroprene sheath compound and heat-resisting and performance synthetic rubber compounds. They were prepared as an emergency measure by Committee D-11 because of the crude rubber situation and the necessity of having standardized requirements for synthetic rubbers that were satisfactory for service in connection with insulated wire and cable. The committee feels that these requirements have proved satisfactory, and that in some cases even with a renewed supply of crude rubber synthetic compounds may continue to be used in certain applications because of the superior properties, and consequently the requirements might well be changed from the emergency to the regular status in A.S.T.M.

Methods of Testing Rubber-Coated Fabrics (D 751 – 43 T).—The new methods for evaluating properties of rubber-coated fabrics which are made by applying either natural rubber compounds or synthetic elastomers processed on rubber machinery resulted from concentrated work by Committee D-11 through a new subcommittee which has had several discussions and correlated the best methods in use. Rubber-coated fabrics have been used for many years, but the war emergency has greatly extended their production and huge quantities are used in connection with life rafts, certain types of boats, balloon cloth, and the like, so that the necessity of adequate standardized methods for evaluating the fabrics has been pressing.

Following a statement on standard condition, the methods provide for the following determinations: dimensions (length, width, thickness and weight); breaking strength, bursting strength, elongation, tearing strength, hydrostatic resistance, and adhesion of coating to fabric. This new standard is being included in Part III of the 1943 Supplement, and is also in the 1944 compilation of A.S.T.M. Standards on Rubber Products now being printed, and copies are available separately.

The subcommittee in charge is carrying out further research work on procedures for evaluating other properties which may be added when agreed upon. However, the basic methods are made available through this new tentative standard.

Requirements for Natural Block Mica and Films Suitable for Use in Fixed Mica-Dielectric Capacitors (D 748):

Approved late in November, but not announced in the December BULLETIN, are new Tentative Specifications for Natural Block Mica and Films Suitable for Use in Fixed Mica-Dielectric Capacitors (D 748 – 43 T). These requirements were prepared in Committee D-9 on Electrical Insulating Materials to meet needs expressed by the War Production Board for standard requirements so that certain imported and domestic micas might be utilized and thus help in procurement and production problems. An introductory note indicates that the properties covered will identify the types of natural block mica suitable for use in the manufacture of fixed mica-dielectric capacitors. As the need for other requirements becomes necessary, it is expected they will be added to the specifications. The note further points out that some micas not conforming to these requirements might be used for other critical electrical insulating purposes, such as vacuum tubes, airplane spark plugs, etc.

Plastics:

New tentative standards* approved on the recommendation of Committee D-20 on Plastics cover *o*-dichlorobenzene (to be incorporated in the Tentative Specifications for Vinylidene Chloride Molding Compounds (D 729 – 44 T)) and provide Methods of Testing Polystyrene which are to be included in the tentative specifications for this material (D 703). Also revisions in the Tentative Method of Test for Compressive Strength of Plastics (D 695 – 42 T) have been accepted, which bring the A.S.T.M. and certain other methods into agreement and include the addition of a statement on offset yield stress and requirements on test specimens where only the modulus and offset yield stress data are desired.

In the determination of viscosity of vinylidene chloride molding compounds (D 729), *o*-dichlorobenzene is used as a solvent, and it was considered necessary that the purity of this material be covered in the specifications.

The methods for testing polystyrene cover determination of viscosity and methanol soluble in the compounds, the viscosity procedure making use of the Tentative Methods of Test for Kinematic Viscosity (D 445 – 42 T). It is indicated that for routine analysis in addition to the Ostwald viscosimeter, calibrated Hoeppler, Ubbelohde, or Saybolt Universal may be used.

Concerning the four other new test methods,* D 756 through D 759, inclusive, as shown in the accompanying list, the following *abstracts* of scope clauses will convey an idea of the nature of these methods:

TENTATIVE METHODS OF TEST FOR RESISTANCE OF PLASTICS TO ACCELERATED SERVICE CONDITIONS (D 756 – 44 T)

Procedures for determining the weight and shape changes occurring in plastics under various conditions of use, not where exposure to direct sunlight, weathering, corrosive atmospheres or heat alone are involved, but where changes in atmosphere temperature and humidity are encountered. This embraces the interior of buildings, and the interior of transport facilities such as motor vehicles, airplane cargo spaces or wing interiors, holds of ships, and railroad cars. Procedures are provided for exposing plastics to combinations of extreme humidity and temperature that will accelerate the changes taking place in the materials kept in sheltered spaces but subject to humidity and temperature variation. Procedures are provided for different types of exposure.

TENTATIVE METHOD OF TEST FOR FLAMMABILITY OF PLASTICS, SELF-EXTINGUISHING TYPE (D 757 – 44 T)

Covers the procedure for determining the flammability of plastics in the form of sheets or plates 1/8 in. in thickness, which are found to be self-extinguishing when tested by the Tentative Method of Test for Flammability of Plastics Over 0.050 in. in Thickness (A.S.T.M. Designation: D 635).

EDITOR'S NOTE.—In an appendix there are included data developed by the chairman of the section responsible for the methods, Dr. Ladislav Boor, covering the establishment of limits of permissible globar temperature. Tests were made on four typical materials, and the results show definitely that a difference of 100 deg. at 900 to 1000 C. does not significantly affect the burning rates. Then to establish necessary wattage to obtain this range of temperature, six globar elements were tested and the table established showing "Wattage-Temperature Characteristics of Types of Elements."

TENTATIVE RECOMMENDED PRACTICE FOR IMPACT STRENGTH OF PLASTICS AT SUBNORMAL AND SUPERNORMAL TEMPERATURES (D 758 – 44 T)

This recommended practice is intended for use in determining impact

* Copies, which should be available in a few weeks, will be sent to members on request.

strength of organic plastics under conditions of low moisture content at temperatures above and below the standard laboratory temperature.

TENTATIVE METHODS OF TEST FOR TENSILE STRENGTH AND COMPRESSIVE STRENGTH OF PLASTICS AT SUBNORMAL AND SUPERNORMAL TEMPERATURES (D 759 – 44 T)

These methods are for use in determining the tensile and compressive properties of organic plastics at temperatures above and below the standard laboratory temperature. They are not intended specifically for use in determining the effect of long continued exposure at elevated or reduced temperatures or of cyclic exposures to ranges of temperature, although they may be used for such special tests if desired.

Correction in Article on Lumber

IN THE OCTOBER, 1943, BULLETIN there was a short announcement of the National Emergency Specifications, WPB Directive No. 29, for the use of Stress Grade Lumber and Its Fastenings for Buildings. The estimated saving from the new stresses allowed and other regulations was incorrectly given, for instead of 150,000 board feet per year as noted, actually the annual saving is expected to reach 200,000,000 board feet.

New Committee Work—Reforging Billets, Roofing Fire Tests, Treated Wood Specifications

COME DEPRESSION, prosperity; war, peace; heat or cold; rather constantly throughout the year there are in course of organization new subcommittees and sections of the A.S.T.M. standing technical committees. These new groups are charged with the development of standards for particular materials, or constituted as study committees to determine whether sufficient information and data are available as a basis for specifications. The following brief notes refer to certain relatively recent new projects. Further details will be given in the annual committee reports or in the BULLETIN.

Reforging Material:

Several years ago Committee A-1 on Steel modernized its requirements for forgings, combining a number of standards into four widely used specifications covering carbon and alloy steel forgings, respectively, for railroad and for miscellaneous industrial uses. A companion specification was developed about this time also intended to supplant other standards which gave requirements on chemical analysis and other properties of billets, blooms, and slabs used for reforging purposes, this material being purchased by various concerns having forge shops. For the past year or two rapid shifts in the chemistry of steels have invalidated parts of this newer specification and the Steel Committee now has a section under the chairmanship of L. E. Ekholm, Alan Wood Steel Co., which soon it is hoped can report favorably to Subcommittee VI on Steel Forgings and Billets headed by J. J. Laudig, an extensively revised proposed standard for carbon and alloy-steel billets, blooms, etc. Further details are expected to be available following the March meetings.

Fire Tests of Roofing Structures and Roof Coverings:

For many years Committee C-5 on Fire Tests of Materials and Construction has been active in its field and the Standard Methods of Fire Tests of Building Construction and Materials (C 19 – 41), and other tests for determining fire-retardant properties of wood, fire tests of door assemblies, etc., are widely used, C 19 in particular being incorporated in many building codes. The necessity of having detailed requirements for tests on roofs and roofing materials has led to the organization of a new subcommittee recently appointed by Mr. R. P. Miller, Committee C-5 chairman. Various organizations concerned are represented and Committee D-8 which prepares specifications and tests for waterproofing and roofing materials is also represented. Mr. H. M. Robinson is serving as chairman of the subcommittee.

Treated Fire-Resistant Wood:

Two A.S.T.M. committees are much concerned with the fire-retardant properties of wood, Committee C-5 on Fire Tests of Materials and Construction which has issued a Test for Fire-Retardant Properties of Wood (C 160 – 41 T), and Committee D-7 on Timber, which is responsible for timber specifications and tests incident thereto. There has been intensified interest in fire-retardant properties, not only because of conflagrations in recent years, but because of the marked increase in the use of treated wood. So that available information can be correlated and the feasibility of specifications be determined, Dr. Hermann von Schrenk, chairman of Committee D-7, is appointing a special subcommittee to consider proposed specifications—one covering the treatment of wood to make it fire-resistant, and another to setup end points for factors beyond which it might be said that wood is not fire resistant; in other words, to determine the efficiency of a specific treatment. Past-President W. H. Fulweiler is subcommittee chairman.

Plastic Cements:

Following through on an urgent request from the War Department, Committee D-20, which has done such outstanding work in developing test methods and specification requirements for a wide variety of plastics, has organized a special subcommittee on plastic cements. Plastic adhesives are extremely important in connection with the fabrication of various products and with no recognized standard tests or specifications, there has been confusion. Considerable correspondence has been exchanged and there have been two meetings, the last one at A.S.T.M. Headquarters on January 19. Various testing procedures that are in use were considered and draft specifications are being developed. Messrs. Robert Burns, Chairman of Committee D-20 on Plastics, and G. M. Kline, Chairman of Subcommittee VI on Specifications, appointed Gerald Reinsmith, Office of Chief of Ordnance, to serve as chairman of the new subcommittee.

Because the new standing committee on adhesives referred to in this BULLETIN will not begin functioning for some little time, it was decided to expedite work on plastic cements in Committee D-20 and later effect the necessary coordination between the two committees.

Test Drafted for Evaluating Hand of Fabrics

Introduction

THESE PROPOSED methods of test were developed during a two-year research project sponsored and directed by the A.S.T.M. Special Committee for Testing of Textile Finishes, of Committee D-13 on Textile Materials. The project was financed by fourteen different companies and institutions and the studies were carried out at the National Bureau of Standards by E. C. Dreby, research associate engaged for the specific purpose. At the Bureau of Standards Mr. Dreby worked under the supervision of W. D. Appel, Chief of the Textile Section. During the research program the special committee functioned under the chairmanship of L. B. Arnold, Jr. (1939 to 1941) and M. C. Moore (1941). At present the affairs of the special committee are administered by G. A. Slowinske, chairman, W. D. Appel, and Miss Laura E. Pratt.

These proposed methods describe the apparatus and detailed procedures for determining the three most important properties which go to make up the hand of a fabric; namely, flexibility, surface smoothness, and fullness. The methods describe in detail the Planoflex apparatus for measuring flexibility by measuring the distortion angle, the Friction Meter for measuring surface smoothness, and the Compression Meter for measuring compressibility. A combination of the measurements made on the Planoflex apparatus and the Compression Meter gives a measure of the fullness of a woven fabric.

The special committee has made arrangements for the manufacture and sale of the three instruments with Sherman W. Frazier, 953 15th St., S.E., Washington, D. C. Drawings showing the details of construction of the instruments may be obtained on application to the American Society for Testing Materials, 260 S. Broad St., Philadelphia 2, Pa.

For detailed information respecting the research program and the data obtained, reference should be made to the following papers by Mr. Dreby:

"The Planoflex, a Simple Device for Evaluating the Pliability of Fabrics," *Journal of Research* of the National Bureau of Standards, Vol. 27, November, 1941, p. 469. (*Research Paper R P1434*).

"The Planoflex, a Simple Device for Evaluating the Pliability of Fabrics," *American Dyestuff Reporter*, Vol.30, November 24, 1941, p. 651.

"Development of Methods for the Evaluation of Textile Finishes," ASTM BULLETIN, No. 114, January, 1942, p. 15.

"Physical Methods for Evaluating the Hand of Fabrics and for Determining the Effects of Certain Textile Finishing Processes," *American Dyestuff Reporter*, Vol. 31, October 12, 1942, p. 497.

"A Friction Meter for Determining the Coefficient of Kinetic Friction of Fabrics," *Journal of Research* of the National Bureau of Standards, Vol. 31, October, 1943, p. 237 (*Research Paper RP 1562*).

"Compression Meter for Evaluating the Compressibility and Resilience of Fabrics" (Publication pending).

Proposed Methods of Test for Evaluation of Properties Related to the Hand of Soft-Finished Woven Fabrics[1]

Distortion Angle, Coefficient of Kinetic Friction, and Total Volume Compression

This is a proposed method and is published as information only. Comments are solicited and should be addressed to the American Society for Testing Materials, 260 S. Broad St., Philadelphia 2, Pa.

Scope

1. (*a*) These methods of test provide procedures for the evaluation of the distortion angle, coefficient of kinetic friction, and total volume compression of soft-finished, woven fabrics for dresses, shirts, and other woven fabrics having similar requirements of the hand.

(*b*) Results obtained by these methods may be used as measures of the pliability and fullness of fabrics and to characterize the nature of the finish of fabrics. The results may only be compared for fabrics of similar fiber composition which vary no more than 5 per cent in number of yarns per inch in either warp or filling and no more than 5 per cent in weight. With these limitations, the measurements may be applied to determine the following characteristics of fabrics:

Pliability.—The distortion angle may be used as a measure of the pliability of fabrics. The greater the distortion angle, the greater the relative pliability.

Fullness.—The ratio of the total volume compression to the distortion angle may be used as a measure of fullness of fabrics. The greater the ratio, the greater the relative fullness.

Finish.—The distortion angle, the coefficient of kinetic friction, and the total volume compression of a fabric together with the fabric's fiber composition, number of yarns per inch, and weight not only specify the nature of the fabric but also rate numerically the essential properties affecting the overall judgment of hand. Thus these values, when taken as a group, may be used to characterize the finish of a fabric. Depending upon the nature of the fabric and the relative effects of these properties affecting the hand, a single numerical value of the overall hand may be obtained by combining the values of these properties according to some suitable numerical relation.[2]

Definitions

2. (*a*) *Distortion Angle.*—The total angle through which a fabric may be distorted in its own plane without producing wrinkles in its surface.

(*b*) *Coefficient of Kinetic Friction.*—The ratio of the force due to friction between two fabric surfaces and the normal force acting on these surfaces when determined under the conditions specified in Section 5 (*b*).

(*c*) *Total Volume Compression.*—The volume change in a fabric produced by a compressive force when determined under the conditions described in Section 6 (*b*).

(*d*) *Pliability.*—The characteristic of a fabric determined by judging its ease of bending with the hands.

(*e*) *Fullness.*—The characteristic of a fabric determined by judging its bulk and ease of bending simultaneously with the hands.

(*f*) *Hand.*—The characteristic of a fabric determined by a mental correlation of all the stimuli induced by those physical properties of a fabric appreciated by the sense of touch.

Test Conditions

3. (*a*) *Test Condition.*—Woven fabrics shall be tested in standard condition, unless otherwise specified.

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[1] These proposed methods are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

[2] Examples of the use of test values for comparative purposes appear in papers by Edwin C. Dreby, "Methods for the Evaluation of Textile Finishes," ASTM BULLETIN, No. 114, January, 1942, p. 15, and "A Friction Meter for Determining the Coefficient of Kinetic Friction of Fabrics," *Journal of Research* of the National Bureau of Standards, Vol. 31, No. 4, October, 1943, pp. 237–246 (*Research Paper RP 1562*).

(*b*) *Standard Condition.*—Standard condition of woven fabrics shall be that reached by the fabric when in moisture equilibrium with a standard atmosphere having a relative humidity of 65 per cent at 70 F. (21 C.). A tolerance of plus or minus 2 per cent is permitted in relative humidity and plus or minus 2 F. (1.1 C.) in temperature.

Distortion Angle

Apparatus

4. The apparatus shall be capable of mounting a 6-in. strip of the test specimen under a 2-lb. tension between two parallel clamps, one of which is constrained to move in an arc so as to maintain a distance of 6 in. between corresponding points on the edges of the two clamps. Provision shall be made for indicating the relative angular displacement of the two clamps in degrees for a range of 45 deg. on each side of the center of the arc made by the movable clamp. The Planoflex apparatus,[3] shown in Fig. 1, is suitable for this test. The procedure described in Section 5 is based on the Planoflex apparatus.[4]

Test Specimens

5. Test specimens shall be 3 ± $^1/_{16}$ in. in width and approximately 10 in. in length with the longer dimension parallel to the warp yarns. The proper width may be obtained by ravelling warp yarns from both sides of a specimen cut a little wider than 3 in. so that all warp yarns run the entire length of the specimen. Specimens shall be cut from unhandled portions of the fabric in such a way that no two specimens contain the same warp or filling yarns. Specimens shall be taken no nearer the selvage than one-tenth the width of the fabric. Three test specimens shall be prepared.

Procedure

6. One end of the specimen shall be clamped centrally in the movable clamp with the filling yarns parallel to the edge of the clamp. The clamp shall be put in the position that makes the specimen pass centrally through the loose jaws of the fixed clamp. The other end of the specimen shall be fastened in the weight clamp which shall then be permitted to hang freely, thus subjecting the specimen to a 2-lb. tension. The fixed clamp shall be tightened. The movable clamp shall then be moved first to the left and then to the right of the midpoint to the positions at which wrinkles just appear diagonally across the center of the specimen. This process shall be repeated several times to obtain a precise observation of the end points of the arc through which the fabric may be distorted without producing wrinkles in its surface. The end points shall be read to the nearest 0.5 deg.

Report

7. The distortion angle shall be the sum of the readings obtained on the left and on the right of the midpoint. The average of the results obtained for the three specimens shall be reported as the distortion angle.

Coefficient of Kinetic Friction

Apparatus

8. The apparatus shall be such that two specimens may be laid face to face on a polished horizontal surface under a 1-lb. weight having a polished bottom surface approximately 3 in. in width by 3½ in. in length. Provision shall be made for drawing the lower specimen from under the upper specimen at a speed of approximately 30 in. per min. A torsion spring, to which the upper specimen can be clamped, shall be used for continuously indicating the frictional force developed between the surfaces of the two specimens when in relative motion. The torsion spring shall be of such capacity that a 0.1-in. displacement at the point of clamping of the specimen is equivalent to a force of 1.5 lb. The indicating device shall be graduated in units of 0.02 lb. The friction meter,[5] shown in Fig. 2, is suitable for this test. The procedure described in Section 9 is based on the friction meter.[4]

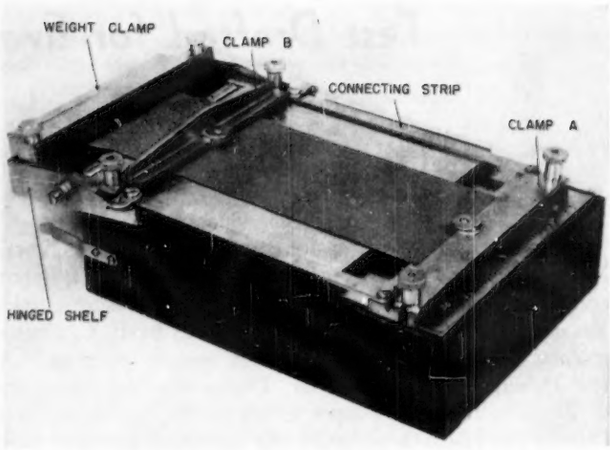


Fig. 1.—Planoflex Apparatus.

Test Specimens

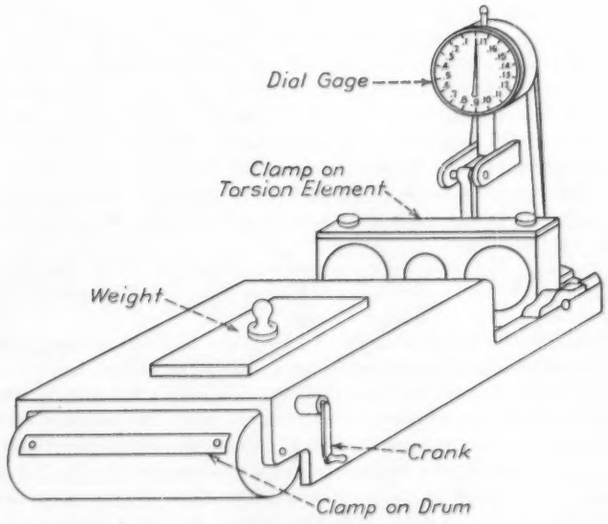
9. Test specimens shall be approximately 4 in. in width and 12 in. in length. Two sets of three pairs of specimens are required, one set for determining the coefficient of kinetic friction in the direction of the warp yarns, having the longer dimension parallel to the warp yarns; and the other set for determining the coefficient in the direction of the filling yarns, having the longer dimension parallel to the filling yarns. No two specimens for the warp direction shall contain the same warp yarns; no two specimens for the filling direction shall contain the same filling yarns. The specimens shall be cut from unhandled portions of the fabric and they shall be taken no nearer the selvage than one-tenth the width of the fabric.

[3] The Planoflex apparatus is described in the paper by Edwin C. Dreby, "The Planoflex, a Simple Device for Evaluating the Pliability of Fabrics," *Journal of Research* of the National Bureau of Standards, Vol. 27, November, 1941, pp. 469–477 (*Research Paper RP 1434*).

[4] Blueprints of detailed drawings for the construction of the Planoflex apparatus, the friction meter, and the compression meter are available at a nominal cost from the American Society for Testing Materials, 260 S. Broad St., Philadelphia 2, Pa.

[5] The frictionmeter apparatus is described in the paper by Edwin C. Dreby, "A Friction Meter for Determining the Coefficient of Kinematic Friction of Fabrics," *Journal of Research* of the National Bureau of Standards, Vol. 31, No. 4, October, 1943, pp. 237–246 (*Research Paper RP 1562*).

[6] The compressionmeter apparatus is described in the paper by Edwin C. Dreby, "A Compression Meter for Evaluating the Compressibility and Resilience of Fabrics," (Publication pending).



Perspective View

Fig. 2.—Friction Meter.

Procedure

10. One of a pair of specimens shall be placed face up on the polished surface of the friction-meter with one end fastened in the clamp on the drum used to impart motion to the specimen. The other specimen shall be placed face down on the first with one end fastened in the clamp on the torsion element. The 1-lb. weight shall be placed carefully in a central position on top of the two specimens. The crank on the drum shall be turned so as to draw the lower specimen at a uniform rate of approximating 30 in. per min. When the end of the lower specimen reaches the back edge of the weight, the specimens shall be returned to their position at the start of the test without removing them from the clamps and the process shall be repeated. The constant or nearly constant value indicated during the latter half of the second stage of the measurement shall be recorded.

Report

11. The average of the results obtained for the three pairs of specimens taken in the warp direction shall be reported as the coefficient of kinetic friction for the warp direction, and the average of the results obtained for the three pairs of specimens taken in the filling direction shall be reported as the coefficient of kinetic friction for the filling direction.

TOTAL VOLUME COMPRESSION

Apparatus

12. The apparatus shall be of the diaphragm type with a fluid pressure medium. The diaphragm surface, through which pressure is transmitted to the test specimen, shall be 3 ± 0.005 in. in diameter. The apparatus shall operate in the pressure range of 0.05 to 0.50 psi., and shall have an accuracy of plus or minus 2 per cent. The apparatus shall be so constructed that the pressure can be applied and released in a uniform and continuous manner. The volume changes shall be indicated in units no greater than 0.0001 cu. in. The compression meter,[6] shown in Fig. 3, is suitable for this test. The procedure described in Section 14 is based on the compression meter.[4]

Test Specimens

13. Test specimens shall be approximately 6 in. square. Five specimens will be required. No two specimens shall contain the same warp yarns or the same filling yarns. The specimens shall be cut from unhandled portions of the fabric and they shall be taken no nearer the selvage than one-tenth the width of the fabric.

Procedure

14. The test specimen shall be secured without wrinkles over the base plate of the apparatus. The upper part of the apparatus shall then be placed on top of the specimen and clamped securely to the base plate so that a pressure of 0.05 psi. or less is applied to the specimen. If the initial adjustment of the instrument was such that the pressure exerted on the test specimen is not 0.05 psi. or less, the instrument shall be readjusted, the specimen discarded, and a new specimen inserted. The pressure shall then be raised to 0.05 psi. and maintained for 30 sec. before recording the position in cubic inches of the volume indicating device. The pressure shall then be increased uniformly over a period of 30 sec. to 0.45 psi., maintaining it at this value for 30 sec., and the position of the volume indicating device again recorded. The difference between the two recorded values shall be the total volume compression for a circular area 3 in. in diameter and a pressure increase from 0.05 to 0.45 psi.

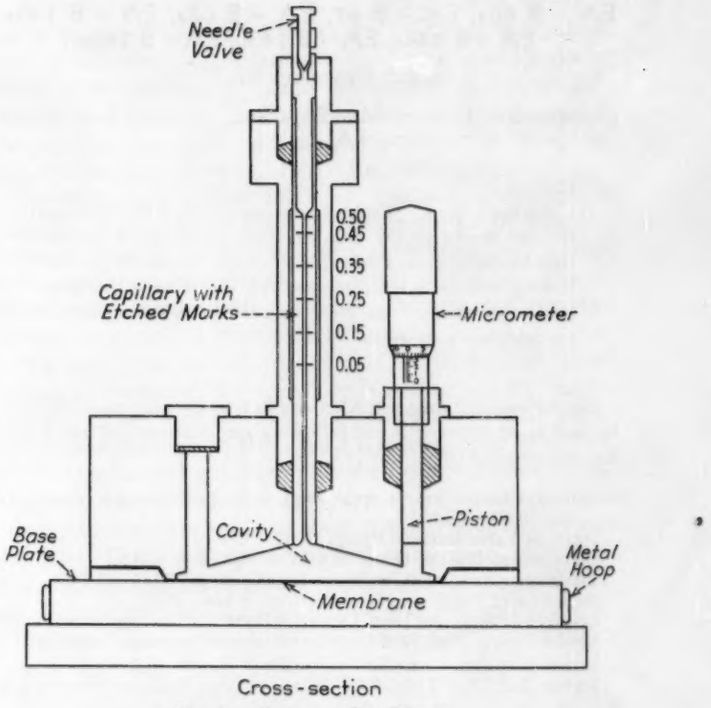


Fig. 3.—Compression Meter.

Report

15. The average of the results of the five individual tests shall be reported as the total volume compression.

L. B. Tuckerman Speaks in Philadelphia

AT A MEETING sponsored by the Philadelphia District Committee at the Franklin Institute on December 16, Dr. L. B. Tuckerman, Assistant Chief, Division of Mechanics and Sound, National Bureau of Standards, Washington, delivered a most interesting talk on problems of critical instability tying in particularly with aircraft design problems. The meeting was preceded by an informal dinner with Dr. Tuckerman as guest. Dean Harvey, A.S.T.M. President, spoke briefly at the meeting.

Following the technical session, a U. S. Steel Corporation film entitled "To Each Other" depicting new developments in steel manufacture and fabrication in some of the huge new plants was shown.

The speaker presented his material in his inimitable way and following discussion of various column theories of Euler, von Kármán, etc., stressed particularly the general theories on critical instability developed by H. M. Westergarde and published in detail in the November, 1921, *Transactions* of the American Society of Civil Engineers. Dr. Tuckerman then discussed Southwark's contribution and related them to Westergarde's general theories, citing an important paper in the Bureau of Standards *Journal of Research* (Paper No. 1163).

There were numerous illustrations of actual failures and finally discussed was a series of equations tying together various stress situations which could arise.

Although the prevalence of colds and grippe, and nearness to Christmas kept the attendance down, there were upward of 75 at the meeting.

EA – B 60a, EA – B 61, EA – B 62a, EA – B 143a, EA – B 144a, EA – B 145a, EA – B 146a

Issued, December 27, 1943

(Superseding Issue of May 26, 1942, in every case except EA – B 61)

EDITOR'S NOTE.—Except in the case of EA–B 61 where the changes shown are the only provisions in effect, each other item has former provisions still in effect; in short, the following material is not complete, but shows only the most recent provisions. See pink slips with 1943 Supplement for complete provisions.

The following Emergency Alternate Provision, when specified, may be used as an alternate in the following specifications and affect only the requirements referred to:

Castings of the Alloy: Copper 88 per cent, Tin 8 per cent, Zinc 4 per cent (B 60 – 41).
Steam or Valve Bronze Castings (B 61 – 42).
Composition Brass or Ounce Metal Castings (B 62 – 41).
Tin-Bronze and Leaded Tin-Bronze Sand Castings (B 143 – 42 T).
High-Leaded Tin-Bronze Sand Castings (B 144 – 42 T).
Leaded Red Brass and Leaded Semi Red Brass Sand Castings (B 145–42 T).
Leaded Yellow Brass Sand Castings for General Purposes (B 146 – 42 T).

Section 7 in EA – B 60a, EA – B 61, and EA – B 62a and Section 9 in EA – B 143a, EA – B 144a, EA – B 145a, and EA – B 146a.

Section 7 or 9.—Change this section which describes the test specimens to read as follows:

7. (*a*) The manufacturer shall have the option of casting test coupons according to Figs. 1, 3, or 4. Because of the web between riser and casting, it is necessary that the gage length of the test specimen prepared from Fig. 1 be machined to the size shown in Fig. 2 before testing.[a]

(*b*) In the case of test specimens prepared from the coupons shown in Figs. 3 or 4, the manufacturer shall have the option of testing the specimen without machining the gage length, or the coupons may be machined to the dimensions shown in Fig. 2. Thus the coupons shown in Figs. 3 or 4 shall be mandatory when the test specimens are tested without machining the gage length. Machined to size test specimens may be prepared to the dimensions of Fig. 2 from the coupons shown in Figs. 1, 3, or 4.

Figs. 3 and 4.—Add the accompanying Figs. 3 and 4 showing the optional coupons for as-cast tension test specimens.

NOTE.—For further information and data, reference may be made to "Studies of Machined *versus* As-Cast Test Specimens for Copper-Base Alloy Sand Castings," Reports to Subcommittee X on Copper-Base Alloys for Sand Castings by J. J. Curran, J. W. Bolton, F. L. Wolf, and W. E. Martin, Report of Committee B-5 on Copper and Copper Alloys, Cast and Wrought, Appendix, *Proceedings*, Am. Soc. Testing Mats., Vol. 42, p. 199 (1942.)

[a] Figures 1 and 2 are given in the respective specifications.

EA – B 22a

Issued, December 27, 1943

(Superseding Issue of December 14, 1942)

The most recent emergency provisions in A.S.T.M. Tentative Specifications for Bronze Castings for Turntables and Movable Bridges and for Bearing and Expansion Plates of Fixed Bridges (B 22 – 42 T) are the same as above, but since Fig. 1 in the regular Specifications B 22 differs from Fig. 1 in the other casting specifications, the pink slip for B 22 will carry an illustration showing the tension test specimen coupon. Figure 2, the standard 2-in. gage length machined tension test specimen, is the same in all the specifications.

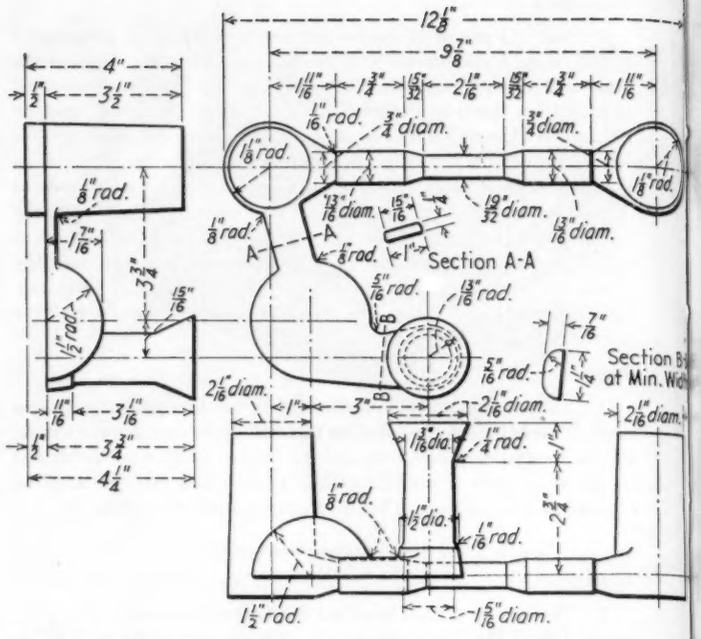


Fig. 3—Optional Coupon for As-Cast Tension Test Specimen, Button H

EA – B 86b

(Standard Specifications for Zinc-Base Alloy Die Castings)
Issued, January 8, 1944

(Superseding Issues of April 6, 1942, and December 31, 1942)

This provision, changing the present requirement for copper in Alloy No. XXIII from "0.10 max." to read "0.25 max." per cent, continues in effect, the recent changes involving the dropping of alloys XXIV and XXVI.

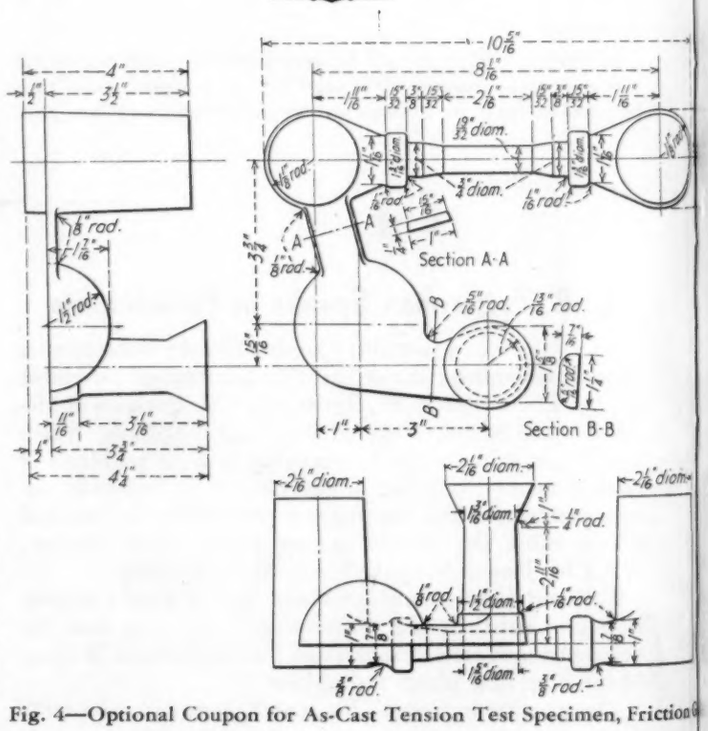


Fig. 4—Optional Coupon for As-Cast Tension Test Specimen, Friction

Vinyl Plastics—Rigid and Nonrigid[1]

by H. L. Drukker

VINYL RESINS date to 1838 when Regnault observed the formation of a white powder when sealed tubes of vinyl chloride stood in sunlight. Subsequently, various chemists and physicists reported their findings over a period of years and patents were granted covering various polymers and copolymers.

Principal commercial types are polymers of vinyl acetate, vinyl chloride, vinyl alcohol; the copolymers of vinyl chloride and vinyl acetate, vinylidene-chloride and vinyl chloride and polyvinyl butyral. Discussions of properties and uses of polyvinyl acetate and polyvinyl alcohol are not included in this paper.

Outstanding properties of polyvinyl chloride and vinyl chloride acetate non-rigid plastics are superior electrical insulation characteristics; low temperature flexibility with good resistance to elevated temperatures, resistance to oxidation, water, most solvents, oils, alkalies, and acids. Rigid vinyl chloride acetate compositions have high dimensional stability due to low moisture absorption, excellent resistance to aging, most solvents, oils, acids, alkalies and are not much affected by low temperature.

Vinylidene chloride polymers are comparatively insoluble, have excellent water resistance and moisture transmission characteristics and in oriented form, very high tensile strength with good flexibility.

Polyvinyl butyrals of the safety glass grade are highly resistant to sunlight, are tough and have very good low temperature characteristics. The "curing" grades are relatively insoluble but are swelled by ketones, esters, and aromatic hydrocarbons. They are flexible at low temperatures yet resist blocking at elevated temperatures.

All vinyl resin compositions are capable of being fabricated by usual methods common to thermoplastic resins, such as calendering, extrusion, molding, heat and pressure forming or laminating. Rigid forms may be cut, milled, sawed or drilled on standard metal working equipment. All soluble types may be applied from solution by spraying, roller coating, spreader coating, or dipping.

Prewar applications included molded transcription records, equipment handles, combs, toothbrush handles, belts and braces, packaging film and sheeting, navigating and calculating instruments, electrical insulation, safety-glass interlayers, wearing apparel, shower curtains, can lining and corrosion-resistant coatings.

Wartime uses include electrical insulation for naval vessels and aircraft, for signal corp wiring and lip microphones. They include food and water bags, drug packages, shoe parts, Arctic tents, raincoats and ponchos, ground cloths and gun covers for the Quartermaster Corps, Ordnance uses include fire control equipment, range calculators, fuse covers, powder bag covers, and heavy gun paulins. The Air Corps uses vinyl-resin-based wing paulins, navigating instruments, grommets, gaskets, upholstery, floor matting, various tubing and wiring supports.

Postwar uses should include wearing apparel both coated and unbacked, packaging films, consumer goods, luggage and upholstery materials, home decorating articles such as wainscoting, wall finishes, drapery, and floor coverings, household articles such as window screens, lighting fixtures, shower curtains, and table covers, insulation for all types of low voltage wiring. Aircraft and automotive fields will use safety glass, molded and extruded parts having improved aging and oil resistance over previously used rubber parts, seat and body upholstery and colorful non-rigid knobs for dashboard instruments, to mention only a few.

[1] For other abstracts of plastic symposium papers, see pages 9–16.

A.S.T.M. MEMBERSHIP

(For complete information see Year Book and literature obtainable from A.S.T.M. Headquarters, 260 South Broad Street, Philadelphia 2, Pa.)

	Entrance Fee	Annual Dues	Publications
MEMBERS—Individuals, companies, associations, laboratories, government departments, technical schools, and libraries.			
Membership Qualifications: Endorsement by two A. S. T. M. members and election by the Executive Committee			
Sustaining Members	$10 Usually waived	$100	All A.S.T.M. publications;[1] also second set of complete Book of Standards and additional copies of BULLETIN without charge on request.
Company Members (Including firms, associations, etc.)	$10	$30	BULLETIN, Year Book, Proceedings, Preprints, Volume on Chemical Analysis of Metals, New and Emergency Standards and Emergency Alternate Provisions, Index to Standards, and one Part of Book of Standards and Supplements. (Two Parts $1.50, all three $2.50 yearly.)
Individual Members (Membership fees and publications furnished are same for Government departments, technical schools, and libraries.)	$10	$15	
JUNIOR MEMBERS—Individuals less than 27 years old. Status changed to members at beginning of next fiscal year after reaching 27 years of age.	$5	$7.50	Same as for Individual Members.
STUDENT MEMBERS—Undergraduate or graduate students in technical schools or students less than 25 years old taking technical courses in an apprentice or night school. Status changed to Junior Member after leaving school.	None	$1.50	BULLETIN, Year Book, Preprints, Special Engineering Student compilation or any one of special compilations of standards.

Cost of Membership in Perpetuity is $600, but is $300 to technical or scientific societies, libraries, and similar organizations. Cost of Life Membership to individuals is based upon age.

[1] This includes many publications not regularly furnished the membership. Full details are available in a booklet describing the advantages of Sustaining Membership.

NOTE—*The current A.S.T.M. Year Book includes, pages 5 through 14, considerable information on publications, meetings, committees, etc., and also, following page 364, a form for recommending prospective members and membership application blanks.*

New Members To January 17, 1944

The following 94 members were elected from November 18, 1943, to January 17, 1944:

Chicago District

Carnegie-Illinois Steel Corp., Gary Steel Works, Plant Library, A. N. Swanson, Chief Metallurgist, Gary, Ind.

Walker Manufacturing Co. of Wisconsin, C. S. McCann, Director of Research, Hamilton and Michigan Blvd., Racine, Wis.

Wells-Gardner and Co., H. B. Canon, Chief Engineer, 2701 N. Kildare Ave., Chicago 39, Ill.

Clope, Spencer L., President, Analytical Research Chemical Laboratory, 1 Main St., Racine, Wis. For mail: 3723 Haven Ave., Racine, Wis.

Debenham, W. Stuart, Ceramic Engineer, Carnegie-Illinois Steel Corp., 208 S. La Salle St., Chicago, Ill.

Doll, Theodore F., Design Engineer, Standard Oil Co. (Indiana), Whiting, Ind. For mail: 33 E. Exchange St., Crete, Ill.

Payne, Frank E., President, Crane Packing Co., 1800 Cuyler Ave., Chicago 13, Ill.

Weber, Peter J. F., Managing Director, E. A. Siebel and Co., 8 S. Dearborn St., Chicago 3, Ill.

Cleveland District

Hall Co., The C. P., J. A. Baty, Chemist, 2510 First Central Tower, Akron 8, Ohio.

Craig, R. W., Chemist, Diamond Alkali Co., Pure Calcium Products Div., Box 407, Painesville, Ohio.

Fisher, Ford, Manager, Maintenance Parts Div., Thew Shovel Co., Loraine, Ohio. For mail: 1815 E. Erie Ave., Lorain, Ohio.

Detroit District

Electric Auto-Lite Co., The, L. H. Middleton, Vice-President, Champlain and Chestnut Sts., Toledo, Ohio.

Fox, Paul N., Mechanical Engineer, Detroit, Toledo & Ironton Railroad Co., Dearborn, Mich. For mail: 4921 Calhoun St., Dearborn, Mich.

Lindeman, A. N., Product Engineer, Penberthy-Injector Co., 1242 Holden Ave., Detroit 2, Mich.

New York District

Casein Company of America, Division of The Borden Company, William F. Leicester, Vice-President, 350 Madison Ave., New York 17, N. Y. [S]*

Angel and Co., Inc., H. Reeve, T. L. Harrocks, Vice-President, 7–11 Spruce St., New York 7, N. Y.

Bordow Co., Henry Cohn, Textile Chemist, 641 Sixth Ave., New York 11, N. Y.

Baccash, John N., Technical Executive, Frank Ix and Sons, Inc., 1441 Broadway, New York, N. Y. For mail: 4824 Forty-third St., Woodside, L. I., N. Y.

Bradford, Victor H., Director of Chemical and Metallurgical Research, Walter Kidde and Co., Inc., 675 Main St., Belleville, N. J. For mail: 168 Beechwood Dr., Packanack Lake, N. J.

de Bellis, A. M., Assistant Inside Plant Manager, Consolidated Edison Co. of New York, Inc., Room 1516, 4 Irving Place, New York 3, N. Y.

Day, Lester E., Materials Engineer, Design Engineering Dept., Westinghouse Electric Elevator Co., 150 Pacific Ave., Jersey City 4, N. J.

Fuller, Arthur W., Test Engineer, Consolidated Edison Co. of New York, Inc., 708 First Ave., New York, N. Y.

Fuller, Dudley D., Instructor, Columbia University, Department of Mechanical Engineering, New York 27, N. Y. For mail: 8425 Eighty-eighth St., Woodhaven, N. Y.

Greenbaum, Sheldon, Chemist, Gordon Lacey Chemical Products Corp., 5702 Forty-eighth St., Maspeth, L. I., N. Y. [J]†

Knapp, Charles A. H., Director, Phelps Laboratories, Boston and Union Sts., Guilford, Conn.

Mazzola, Joseph R., Chief Engineer, Automatic Winding Co., 900 Passaic Ave., East Newark, N. J.

Phillips, William J., Sales Engineer, The Symington-Gould Corp., 230 Park Ave., New York, N. Y. For mail: 23 Haven Ave., New York 32, N. Y.

Rambo, John Chester, Analytical Chemist, New York Navy Yard, Brooklyn, N. Y. For mail: 179 St. John's Pl., Brooklyn 17, N. Y.

Schaffner, Charles E., Instructor, Civil Engineering Dept., The Cooper Union, Cooper Square, New York 3, N. Y. [J]

Smith, Carlos B., Chief Engineer, Bullock-Smith Associates, 136 Liberty St., New York 6, N. Y.

Staebner, W. H., Charles Pfizer and Co., Inc., 11 Bartlett St., Brooklyn 6, N. Y.

Vahlteich, H. W., Vice-President in Charge of Research and Quality Control, The Best Foods, Inc., Bayonne, N. J.

Northern California District

Gardiner Manufacturing Co., Thomas R. Gardiner, General Manager, 2707 Union St., Oakland 7, Calif.

Philadelphia District

Crowell, Walter S., Supervising Chemical Engineer, The S. S. White Dental Manufacturing Co., 211 S. Twelfth St., Philadelphia 7, Pa.

Decker, John C., Jr., Physical Chemist, Brewster Aeronautical Corp., Johnsville, Pa. For mail: 7 Edgehill Rd., Abington, Pa. [J]

Haller, Herbert C., Chief Chemist, Continental Mills, Inc., Lena and Armat Sts., Philadelphia 44, Pa.

Lamborn, Samuel W., Senior Assistant Mechanical Engineer, Department of City Transit, 1304 City Hall Annex, Philadelphia, Pa. For mail: Somerton, Philadelphia 16, Pa.

Pearce, William T., Consultant on Organic Coatings, National Research Council, Committee on Quartermaster Problems, Temple University, Philadelphia, Pa. For mail: 512 Merwyn Rd., Narberth, Pa.

Ring, Charles N., Field Engineer, Magnaflux Corp., New York, N. Y. For mail: 2499 N. Fiftieth St., Philadelphia 31, Pa.

Pittsburgh District

Preston Laboratories, Frank W. Preston, Director, Box 847, Butler, Pa.

Claypoole, Richard W., Chief Metallurgist, Edgar Thomson Works, Carnegie-Illinois Steel Corp., Braddock, Pa.

Moorhead, Thomas E., Ellwood Works, National Tube Co., Ellwood City, Pa.

St. Louis District

Green, Floyd S., Electrical Engineer, Frank Adam Electric Co., Box 357, St. Louis 3, Mo.

Southern California District

Consolidated Vultee Aircraft Corp., E. W. Berger, Chief, Manufacturing Research, San Diego 2, Calif.

Mead, Loyd W., Tool Steel and Carbide Engineer, Firth-Sterling Steel Co., 1327 Santa Fé Ave., Los Angeles, Calif. For mail: 1434 Hill Dr., Los Angeles 41, Calif.

Western New York-Ontario District

du Pont de Nemours and Co., Inc., E. I., Rayon Dept., Nelson Allen, Supervisor, Cellophane Research Section, Buffalo, N. Y.

National Metal Co., Division of Frankel Brothers, Ltd., Leo M. Frankel, Manager, Don Roadway and Eastern Ave., Toronto, Ont., Canada.

Miserentino, Charles O., Chief Chemist, Dunlop Tire and Rubber Corp., Buffalo 7, N. Y.

U. S. and Possessions

Other than A.S.T.M. Districts

Basic Magnesium, Incorporated, C. H. Mahoney, Chief Metalurgist, Box 1150, Las Vegas, Nev.

B. B. Chemical Co., Thomas C. Morris, Research Chemist, 784 Memorial Dr., Cambridge 39 Mass.

Chicopee Manufacturing Corp., Research Division, C. H. Plummer, Research Engineer, Chicopee Falls, Mass.

Commercial Steel Casting Co., The, Robert A. Willey, Metallurgist, Cheney Ave., Marion, Ohio.

Crescent Co., Inc., The, Wilbur Birkitt, Chief Chemist, 32 Central Ave., Pawtucket, R. I.

Dana Warp Mills, Luther Dana, President and Assistant Treasurer, Westbrook, Me.

Durametallic Corp., R. E. Morgan, Chief Engineer, 2104 Factory St., Kalamazoo 24F, Mich.

General Armature Corp., J. F. Cullin, Chief Engineer, 205 Prospect St., Lock Haven, Pa.

Haskelite Manufacturing Corp., J. H. Tigelaar, Director of Research and Test, 701 Ann St., N. W., Grand Rapids 2, Mich.

Hunt Machine Co., Rodney, Robert L. Hatch, Engineer, 46 Mill St., Orange, Mass.

Reilly Tar and Chemical Corp., Malcolm Mitchell, Engineer, 1615 Merchants Bank Bldg., Indianapolis 4, Ind.

VIRGINIA-LINCOLN CORP., J. D. Lincoln, Vice-President, Marion, Va.

ZENITH OPTICAL CO., L. M. Polan, Technical Director, 220 Eighth St., Huntington 19, W. Va.

ANGIER, JAMES F., Senior Airways Engineer, Standards and Specifications Section, Civil Aeronautics Administration, Washington, D. C. For mail: 239 Maple Ave., Washington 12, D. C.

BOCK, MICHAEL, II, Assistant Metallurgist, U. S. Navy Yard, Boston, Mass. For mail: 89 Marion St., Brookline, Mass. [J]

BUTLER, GURDON M., JR., Chief Metallurgist, Allegheny-Ludlum Steel Corp., Howard Ave., Dunkirk, N. Y. For mail: 109 Forest Place, Fredonia, N. Y.

CARDELL, JAMES, Process Engineer, Raytheon Production Corp., 55 Chapel St., Newton, Mass.

CATHOLIC UNIVERSITY OF AMERICA, THE, DEPARTMENT OF CIVIL ENGINEERING, Washington 17, D. C.

CLARKE, FRED W., Architect, 1900 Merchants National Bank Bldg., Box 301, Mobile 2, Ala.

CONLON, J. T., Chief Engineer, Gustin-Bacon Manufacturing Co., 1412 W. Twelfth St., Kansas City, Mo.

DYER, J. ROBERT, JR., Secretary, The Indium Corp. of America, 1676 Lincoln Ave., Utica, N. Y.

ELCHINGER, CHARLES F., Proprietor, Charles F. Elchinger—Successor to Koretke Brass and Manufacturing Co., Ltd., 922–26 Magazine St., New Orleans 13, La.

FINCH, ROGERS B., Officer in Charge, Textiles and Textile Products Section, Engineering Div., Jeffersonville Quartermaster Depot, Jeffersonville, Ind. [J]

JENNINGS, JAMES CHRISTOPHER, JR., Junior Chemical Engineer, Clinton Engineer Works, Tennessee Eastman Corp., E. V. 4, Room 130, Oak Ridge, Tenn. [J]

LYNCH, THOMAS E., Chief of Mechanical Testing Lab., Aluminum Company of America, Cressona, Pa.

MABE, RALPH W., Bridge Engineer, The Nashville, Chattanooga & St. Louis Railway, 930 Broadway, Nashville 3, Tenn.

NEBESAR, ROBERT J., Chief Engineer, Universal Moulded Products Corp., Bristol Aircraft Division, Bristol, Va.

PARKER, CHARLES FULTON, Chief Engineer, W. H. Hinman, Inc., N. Anson, Me. For mail: Lower Main St., Gorham, Me.

PINSKY, SARA, Textile Technician, Fashion Frocks, Inc., 3301 Colerain St., Cincinnati 25, Ohio. [J]

RAFTER, J. RICHARD, Chemist, Providence Braid Co., Box 1271, Providence 1, R. I.

REARDON, C. E., Superintendent, Metallurgical, Chemical and Inspection Dept., Geneva Steel Co., Box 269, Salt Lake City, Utah.

STONE, ALBERT RIVINGTON, Assistant Chief Engineer, Gerotor May Division, May Oilburner Corp., Baltimore, Md. For mail: 705 Dunkirk Rd., Baltimore 12, Md.

TITUS, JAMES W., Engineer, U. S. Navy, Naval Research Lab., Bellevue, Washington 20, D. C. For mail: 3954 Second St., S. W., Washington 20, D. C. [J]

WORNER, RUBY K., Associate Textile Technologist, U. S. Department of Agriculture, Southern Regional Research Lab., 2100 Robert E. Lee Blvd., New Orleans 19, La.

Other Than U. S. and Its Possessions

BOEING AIRCRAFT OF CANADA, LTD., Ivon Garcia, Laboratory Supervisor, Vancouver A.M.F., B. C., Canada.

BROKEN HILL PROPRIETARY CO., LTD., Keith Butler, Manager, Newcastle, N.S.W., Australia.

COCKSHUTT PLOW CO., LTD., THE, G. N. Wedlake, Metallurgical Engineer, Brantford, Ont., Canada.

LYSAGHT'S NEWCASTLE WORKS PROPRIETARY, LTD., R. Parry Okeden, Managing Director, Tirrikiba P. O., N.S.W., Australia.

WIMPEY AND CO., LTD., GEORGE, S. J. Widger, Progress and Planning Dept., Tilehouse Lane, Denham, Uxbridge, Middlesex, England.

CARTWRIGHT, W., Thomas Bolton and Sons, Ltd., Froghall, North Staffordshire, England.

GIDVANI, B. S., Acting Director, London Shellac Research Bureau, India House, Aldwych, London W. C. 2, England.

HAENNI, P. M., Director of Research, Aluminium Laboratories Limited, Box 84, Kingston, Ont., Canada.

OLDHAM, ROBERT A., Electrical Engineer, Federal Wire and Cable Co., Ltd., Guelph, Ont., Canada.

PHILLIPS, ALBERT G., Consulting City Chemist, City of Winnipeg, and President, The National Testing Laboratories, Ltd., 223 James St., Winnipeg, Man., Canada.

PLUMMER, R. W., Technical Director, Industrias Quimicas Argentinas "Duperial," Paseo Colon 285, Buenos Aires, Argentina.

SLATER, W. F., Thomas Bolton and Sons, Ltd., Froghall, North Staffordshire, England.

* [S]—Denotes Sustaining Member.
† [J]—Denotes Junior Member.

Personals

• • • News items concerning the activities of our members will be welcomed for inclusion in this column.

E. J. RUTAN, formerly Electrical Engineer, Sherman, Boland & Boyce, New York, N. Y., is now Vice-President, Rutan & Snead, Inc., New York. This new organization offers a service as industrial consultants for machine and product development and design, for work on mechanical, electrical, and electronic equipment and related problems.

W. L. EGY is now Plant Manager, Sonotone Corp., White Plains, N. Y. He was connected with the Instrument Division, Zenith Optical Co., Huntington, W. Va., as General Manager.

WILLIAM A. McINTYRE, who was Assistant Metallurgist, The McKinnon Industries, Ltd., St. Catharines, Ont., Canada, is now Metallurgist, Thompson Products, Ltd., St. Catharines.

IRVING HOCHSTADTER, formerly President, Stillman & Van Siclen, Inc., New York, N. Y., is now Research Administrator, Gallowhur Chemical Corp., New York, N. Y.

G. A. LUX, is now Director, Technical Information, Oakite Products, New York, N. Y. He was formerly Development Engineer, Divine Brothers Co., Inc., Utica, N. Y.

JESSE T. LITTLETON has been made a Vice-President and Co-director of Research for the Corning Glass Works, Corning, N. Y. He was formerly Assistant Director of Research.

RAY B. CREPPS is Director of Testing Division, Owens-Corning Fiberglas Corp., Research Laboratories, Newark, Ohio. He was connected with Purdue University, Lafayette, Ind., as Associate Professor of Civil Engineering, Engineering Experiment Station.

ARTHUR SCHRODER, for some time has been Director of Research of E. H. Sargent & Co., a leading laboratory supply house in Chicago, Ill. Several years prior to this he was Research Chemist, Pure Oil Co., in Winnetka, Ill., and previous to that was extremely active in various phases of the instruments and laboratory supply field.

B. B. BACHMAN, Engineer, The Autocar Co., Ardmore, Pa., has been elected treasurer of the Society of Automotive Engineers, it was announced at the business session of the society's annual meeting in Detroit in January.

GEORGE GRANGER BROWN, Professor of Chemical Engineering and Chairman, Department of Chemical and Metallurgical Engineering, University of Michigan, Ann Arbor, Mich., is the new president of the American Institute of Chemical Engineers.

J. K. RUMMEL, Chief Chemist of the Shanghai Power Co., Shanghai, China, returned to America on the *Gripsholm* and is now located at Ebasco International Corp., 2 Rector St., New York, N. Y.

WILLIAM P. PUTNAM, President, Treasurer, and Technical Director of The Detroit Testing Laboratory was the subject of the "We Congratulate" column in the Detroit *Free Press* recently, in honor of 40 years of successful operation of his own company of which he has been the only president.

RALPH L. WILSON has been appointed Chief Metallurgical Engineer, Steel and Tube Division, The Timken Roller Bearing Co., Canton, Ohio. For a considerable time he was very active in the War Production Board's Iron and Steel Branch, and has been Metallurgical Engi-

neer for the Climax Molybdenum Co., in Canton. A number of years ago, Mr. Wilson was a member of the Steel and Tubes Division Technical Staff of The Timken Roller Bearing Co.

C. W. BLACKETER, formerly Director of Developments, Martin Varnish Co., Chicago, Ill., is now Chemist, Tungsten Plantation, Lamont, Fla.

R. M. GREEN is Professor of Civil Engineering and Chairman of Civil Engineering Department, University of Nebraska, Lincoln, Nebr. He was President, Western Laboratories, Lincoln, Nebr.

JAMES H. HERRON, President, The James H. Herron Co., Cleveland, Ohio, received the Honorary Degree of Doctor of Engineering from the Case School of Applied Science. The degree was given at the college's graduation exercises held on December 20, 1943. A past-president of the A.S.M.E., Doctor Herron has been active in A.S.T.M work, and served as chairman of the Cleveland District Committee several years ago.

J. A. KIRKPATRICK is now connected with the Tubular Alloy Steel Corp., Gary, Ind. He was formerly Superintendent of Inspection, Ellwood Works, National Tube Co., Ellwood City, Pa.

L. C. HEWITT has been elected Vice-President of the Laclede-Christy Clay Products Co., St. Louis, Mo. In addition to participating in management affairs, he continues in charge of research and control. He was formerly Director of Research for the company.

F. C. HOUGHTEN, now a Lieutenant Commander, U. S. Naval Reserve, Research Division, Bureau of Medicine and Surgery, has been awarded the F. Paul Anderson Medal of the American Society of Heating and Ventilating Engineers. This award is made to him "for outstanding research over a long period of years in the fields of heating, ventilating and air conditioning, resulting in distinct benefits to the public and the nation; for advancement of the knowledge of the physiological reactions of persons to their environments and for the careful presentation of technical data readily adaptable to general use in engineering." Presentation of the medal will be made on February 2, on the occasion of the Banquet at the Hotel Pennsylvania, New York, during the Fiftieth Annual Meeting of the A S H.V.E.

W. T. BROWN, formerly Manager, Coal, Coke and By-Product Research, Jones & Laughlin Steel Corp., Pittsburgh, Pa., is now Consultant, Coal, Coke and By-Products, 615 Grant Building, Pittsburgh, Pa.

LEIGHTON M. LONG, formerly Chief Metallurgist and Foundry Superintendent, Bunting Brass and Bronze Co., Toledo, Ohio, has been named an Assistant Research Supervisor at Battelle Memorial Institute, Columbus, Ohio.

WESLEY R. NELSON, who for several years has been Chief of the Engineering Division, U. S. Bureau of Reclamation, Washington, D. C., has been appointed one of the six regional directors in the important new decentralization move of the Bureau of Reclamation. As Director of Region No. 5, Mr. Nelson will have his headquarters in Amarillo, Texas. He has been quite active in A.S.T.M. work, particularly in the field of soils for engineering purposes where he served as secretary of A.S.T.M. Committee D-18.

ROBERT F. BLANKS, Materials and Testing Engineer, U. S. Bureau of Reclamation, Denver, Colo., recently received the Award of Excellence presented by the Department of the Interior "for ingenuity, efficiency, and inventive talents displayed in the Government service." Mr. Blanks is responsible for the invention of equipment for improving accuracy and uniformity in testing the strength of materials.

ALEXANDER FOSTER, JR., Vice-President, Warner Co., Philadelphia, Pa., member of the A.S.T.M. Executive Committee, now has the responsibility for all operating activities for his company excepting the Bellefonte Division. In addition to distributing yards, marine operations, maintenance department and sand and gravel plants already under his responsibility, several lime plants are now in this group.

J. J. BOWMAN, Aluminum Co. of America, Secretary of A.S.T.M. Committee E-4 on Metallography, who for many months has been Consultant in the WPB Conservation Division in Washington, has now returned to active work with his company and is located in the Pittsburgh office concentrating on specifications work. He is devoting a portion of his time each week as Consultant in Washington.

DEANE B. JUDD has been elected President of the newly organized Munsell Color Foundation, Inc., which has received control of the Munsell Color Co., Inc. This Foundation, a nonprofit group has as its chief aim furthering the scientific advancement of color knowledge, particularly relating to standardization, nomenclature, and specification of color. The board of directors is to be appointed by various organizations, Mr. Judd being appointed by the Director of the National Bureau of Standards.

CLAUDE ROY PFLASTERER, who was Metallurgical Engineer, Union Pacific Railroad Co., Omaha, Nebr., is now Engineer of Tests for the company.

JOHN W. KENNEDY, who has been active in the work of the Detroit District Committee, is now General Sales Manager, Huron Portland Cement Co., Detroit, Mich. He was formerly Assistant Sales Manager.

L. J. MARKWARDT, Chief, Division of Timber Mechanics, U. S. Forest Products Laboratory, Madison, Wis., has recently been appointed Assistant Director of the Laboratory. Mr. Markwardt is Secretary of A.S.T.M. Committee D-7 on Timber, and was the 1943 Edgar Marburg Lecturer.

W. P. EDDY, JR., formerly Executive Engineer with the Yellow Truck and Coach Mfg. Co., Pontiac, Mich. is now employed by the Pratt and Whitney Aircraft Division, United Aircraft Corp., East Hartford, Conn., as Materials Engineer.

NECROLOGY

We announce with regret the death of the following members and representatives:

JAMES L. HEITZMAN, Vice-President, E. L. Conwell and Co., Philadelphia, Pa. Member since 1932. Mr. Heitzman served as a member of Committee C-1 on Cement since 1932.

D. W. MCNAUGHER, Vice-President and Treasurer, Robert W. Hunt Co., Pittsburgh, Pa. Member since 1904.

JOHN F. O'REILLY, Operative Plasterers' and Cement Finishers' International Association of United States and Canada, Jersey City, N. J. At the time of his death Mr. O'Reilly was a member of Committees C-7 on Lime and C-11 on Gypsum and Subcommittee II on Gypsum Plasters and represented the Operative Plasterers' and Cement Finishers' International Association of United States and Canada on Sectional Committee A 42 on Specifications on Plastering.

J. S. RICHARDS, Director of Research, American Steel and Wire Co., Cleveland, Ohio. Mr. Richards represented his company in its membership on Committee A-1 on Steel since 1936.

KURT E. RIPPER, Chief Technologist, Plastics Div., American Cyanamid Co., New York, N. Y. Member since 1939.

CHARLES PAUL TEEPLE, Vice-President, In Charge of Research, Crane Packing Co., Chicago, Ill. Member since 1943.

FRANK M. ANDREWS, Secretary, Andrews Steel Co., Newport, Ky. Member since 1923.

Steel Standards for Spectrography

ANNOUNCEMENT is made in the December issue of the *Technical News Bulletin* of the National Bureau of Standards of the stocking of a number of steels in rod form suitable for controls in spectrographic analysis. The 18 standards were selected to enable checking of composition among several types of carbon and low-alloy steels, and should provide an analytical curve for manganese, silicon, copper, nickel, chromium, vanadium, and molybdenum. A list of the new special steel standards and information on procurement can be obtained from the Bureau.

Complete List of A.S.T.M. Emergency Specifications and Emergency Alternate Provisions

EDITOR'S NOTE.—The emergency specifications listed below are published in the Book of Standards or 1943 Supplements and are also available in separate pamphlet form. The emergency alternate provisions are issued as pink slips furnished with the respective Books of Standards and Supplements. They are also furnished with each separate copy of the standards. The emergency provisions also have been published in the various ASTM BULLETINS as the provisions have been issued.

January 8, 1944

Emergency Specifications for

ES-1a Lead-Coated and Lead-Alloy Coated Copper Wire for Electrical Purposes.
ES-2 Lead Coating (Hot-Dip), on Iron or Steel Hardware.
ES-3 Conducting Salt Spray Tests on Organic Protective Coatings. (Method)
ES-4 *Discontinued*—Replaced by E 33-42.
ES-5a Carbon-Chromium Ball and Roller-Bearing Steels.
ES-6a GR-S Synthetic Rubber Sheath Compound for Electrical Insulated Cords and Cables Where Extreme Abrasion Resistance Is Not Required.
ES-7 Fire-Refined Copper for Wrought Products and Alloys.
ES-8 85 Per Cent Magnesia Thermal Insulating Cement.
ES-9 Long Fiber Asbestos Thermal Insulating Cement.
ES-10 Mineral Wool Thermal Insulating Cement.
ES-11 Expanded or Exfoliated Mica Thermal Insulating Cement.
ES-12 Diatomaceous Earth Thermal Insulating Cement, for Use from 600 to 1200 F.
ES-13 Diatomaceous Earth Thermal Insulating Cement, for Use from 1200 to 1900 F.
ES-14 Blanket Thermal Insulation for Building Purposes.
ES-15 Blanket Thermal Insulation for Industrial Purposes.
ES-16 Blanket Thermal Insulation for Refrigeration.
ES-17 Preformed Pipe Covering Thermal Insulation.
ES-18 Preformed Block Thermal Insulation.
ES-19 Structural Board Thermal Insulation.
ES-20 Malleable Iron Flange, Pipe Fittings, and Valve Parts.
ES-21 Carbon-Steel and Alloy-Steel Forgings for Magnetic Retaining Rings for Turbine Generators.
ES-22 Alloy-Steel Forgings for Nonmagnetic Coil Retaining Rings for Turbine Generators.
ES-23 Carbon-Steel Forgings for Rings for Main Reduction Gears.
ES-24 Carbon-Steel and Alloy-Steel Forgings for Pinions for Main Reduction Gears.
ES-25 Carbon-Steel and Alloy-Steel Forgings for Turbine Generator Rotors and Shafts.
ES-26 Carbon-Steel and Alloy-Steel Forgings for Turbine Rotors and Shafts.
ES-27 Carbon-Steel and Alloy-Steel Forgings for Turbine Bucket Wheels.
ES-28 *Discontinued*—Replaced by D 752-43 T.
ES-29 Special Quality Aluminum Die Castings.
ES-30 *Discontinued*—Replaced by D 753-43 T.
ES-31 Electrodeposited Coatings of Lead on Steel.
ES-32 Method of Test for Color of U. S. Army Motor Fuel (All-Purpose) by Means of an A.S.T.M. Color Standard
ES-33 *Discontinued*—Replaced by D 754-43 T.
ES-34 *Discontinued*—Replaced by D 755-43 T.

Emergency Alternate Provisions in Specifications for

Steel

EA-A 1 Open-Hearth Carbon-Steel Rails (A 1-39).
EA-A 21 Carbon-Steel Axles for Cars and Tenders (A 21-39).
EA-A 25a Wrought Steel Wheels for Electric Railway Service (A 25-41).
AE-A 26 Steel Tires (A 26-39).
EA-A 27 Carbon-Steel Castings for Miscellaneous Industrial Uses (A 27-42).
EA-A 30 Boiler and Firebox Steel for Locomotives (A 30-42).
EA-A 53 Welded and Seamless Steel Pipe (A 53-42).
EA-A 57 Multiple-Wear Wrought Steel Wheels (A 57-39).
EA-A 67 Steel Tie Plates (A 67-33).
EA-A 70 Carbon-Steel Plates for Stationary Boilers and Other Pressure Vessels (A 70-42).
EA-A 83 Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83-42).
EA-A 87 Carbon-Steel and Alloy-Steel Castings for Railroads (A 87-42).
EA-A 89 Low-Tensile Strength Carbon-Steel Plates of Flange and Firebox Qualities (A 89-43).
EA-A 120 Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses (A 120-42).
EA-A 134 Electric-Fusion-Welded Steel Pipe (Sizes 30 in. and Over) (A 134-42).
EA-A 135 Electric-Resistance-Welded Steel Pipe (A 135-42).
EA-A 139a Electric-Fusion-Welded Steel Pipe (Sizes 8 in. to but not Including 30 in.) (A 139-42).
EA-A 148a Alloy-Steel Castings for Structural Purposes (A 148-42).
EA-A 158 Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A 158-42 T).
EA-A 160 Axle-Steel Bars for Concrete Reinforcement (A 160-39).
EA-A 161 Seamless Low-Carbon and Carbon-Molybdenum Steel Still Tubes for Refinery Service (A 161-40).
EA-A 167a Corrosion-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip (A 167-43).
EA-A 177 High-Strength Corrosion-Resisting Chromium-Nickel Steel Sheet and Strip (A 177-42).
EA-A 178 Electric-Resistance-Welded Steel and Open-Hearth Iron Boiler Tubes (A 178-40).
EA-A 179 Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes (A 179-42).
EA-A 183 Heat-Treated Carbon- and Alloy-Steel Track Bolts and Nuts (A 183-40 T).
EA-A 186 One-Wear and Two-Wear Wrought Steel Wheels (A 186-39).
EA-A 190 Lightweight and Thin-Sectioned Gray-Iron Castings (A 190-40).
EA-A 192 Seamless Steel Boiler Tubes for High-Pressure Service (A 192-40).
EA-A 194 Carbon and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service to 1100 F. (A 194-40).
EA-A 199 Seamless Cold-Drawn Intermediate Alloy-Steel Heat-Exchanger and Condenser Tubes (A 199-40).
EA-A 200 Seamless Intermediate Alloy-Steel Still Tubes for Refinery Service (A 200-40).
EA-A 201 Carbon-Silicon Steel Plates of Ordinary Tensile Ranges for Fusion-Welded Boilers and Other Pressure Vessels (A 201-43).
EA-A 202 Chrome-Manganese-Silicon (CMS) Alloy-Steel Plates for Boilers and Other Pressure Vessels (A 202-39).
EA-A 203 Low-Carbon Nickel-Steel Plates for Boilers and Other Pressure Vessels (A 203-42).
EA-A 204 Molybdenum-Steel Plates for Boilers and Other Pressure Vessels (A 204-42).
EA-A 206 Seamless Carbon-Molybdenum Alloy-Steel Pipe for Service at Temperatures from 750 to 1000 F. (A 206-42 T).
EA-A 209 Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes (A 209-42).
EA-A 211 Spiral-Welded Steel or Iron Pipe (A 211-40).
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